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MISA

Municipal/Industrial Strategy for Abatement

A STUDY OF THE EFFECTS OF IN-PLACE POLLUTANTS ON THE BOTTOM WATER, SEDIMENTS AND SEDIMENT-DWELLING ORGANISMS OF CANAGAGIGUE CREEK AT ELMIRA, ONTARIO, 1987

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A STUDY OF THE EFFECTS OF IN-PLACE POLLUTANTS ON THE BOTTOM WATER, SEDIMENTS AND SEDIMENT-DWELLING ORGANISMS OF CANAGAGIGUE CREEK AT ELMIRA, ONTARIO, 1987

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SUMMARY

In 1987 a survey of Canagagigue Creek was undertaken as part of the Municipal-Industrial Strategy for Abatement (MISA) Pilot Site study to evaluate the extent of contamination of the bottom sediments and the effects, if any, of the contaminants on the resident biota. A number of potential sources of contaminants exist along the creek, the most notable ones being the Uniroyal Chemical plant and the Elmira Sewage Treatment Plant. Additional sources within the watershed include agricultural and urban runoff.

A significant finding of this study is the occurrence of DDT and its metabolites DDD and DDE. It appears that sources exist within the drainage basin, especially at the Uniroyal site. Levels in sediments were particularly high during spring runoff. Although levels declined in the fall, high residual levels were found. The sediments of Canagagigue Creek also contained a number of other organic compounds, such as PAHs, that can potentially be bioaccumulated by aquatic organisms.

The specific areas addressed by the study are summarized below.

1. The Elmira STP appears to be contributing to elevated levels of phosphorus, chloride, sulphate, ammonium and nitrite in the stream. Sediment concentrations of these chemicals decreased with distance downstream of the plant, but levels were still above background as far as 3 km downstream of the plant.

2. Concentrations of most organic contaminants in water were below detection levels, though increases were noted in water concentrations of some of the chlorophenols below the Uniroyal site.

3. Sediment metal concentrations were generally lower at upstream areas, though levels varied in relation to sediment organic matter. Levels of some metals increased slightly downstream of the STP (copper and chromium) and below the Uniroyal site (lead).

4. Most organics were below detection levels in the sediments with the exception of DDT and its derivatives DDD and DDE. Sediment levels of these were very high in the spring and may be a reflection of material introduced with the spring runoff. Levels were lower in the fall, but still well above the upstream levels, suggesting the bottom is not thoroughly scoured and residual deposits may remain for some time. Sediment levels were highest at the STP site in the spring (6,030 ug/g pp-DDT) and exceeded the Severe Effect Levels of the proposed Provincial Sediment Quality Guidelines immediately below the STP. However, an increase in the levels in sediment was first detected at the Uniroyal site. Levels were highest in sediments at the Uniroyal site in the fall (300 ng/g pp-DDD).

5. Chlorophenols, though present in the water column, were not detected in the sediments

6. Sediment levels of a number of PAH compounds were significantly higher at the Uniroyal site and decreased steadily downstream.

7. Tissue concentrations of copper, cadmium, arsenic, mercury and zinc in benthic organisms were higher than sediment concentrations. Only zinc, cadmium and mercury increased in tissues below the Uniroyal or STP sites compared to tissue levels in benthos at the control site.

8. Organic compounds did not bioaccumulate to any significant degree in benthic organisms. Concentrations of DDT and related compounds, though very high in sediments, were low in benthic organisms.

9. No significant increases in tissue metal concentrations could be detected in bottom-feeding fish collected in this study. Accumulation of pp-DDE did occur in one species downstream of the STP.

10. Laboratory sediment bioassay results on fathead minnows suggested the presence of a toxic effect in the sediments from the Uniroyal site. A likely candidate may be an organic contaminant such as one of the DDT group of compounds. This warrants further investigation.

11. Bioaccumulation of a number of contaminants occurred in both fathead minnows and mayflies during laboratory tests on sediments from areas downstream of the control. Disturbance of the sediments appears to increase the availability of some of the contaminants.

12. Effects of sediment contamination on the species composition and density of the benthic community could not be differentiated from other effects. A suppression of both organism density and diversity were noted below the STP outfall, and these can be attributed to a combination of sediment type and the concentrations of contaminants in the water. The benthic community in general appears to be strongly influenced by the presence of organic matter, (likely a result of agricultural activity within the drainage basin), which obscures any potential effects from contaminants.

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1. INTRODUCTION

As part of the Municipal-Industrial Starategy for Abatement (MISA) Pilot Site program, a study was carried out along Canagagigue Creek in the vicinity of the Elmira Sewage Treatment Plant in 1987 to determine the environmental impacts of contaminated sediments. Studies have shown that sediments may act both as a sink for contaminants and as reservoirs for future release to the water column. Contaminants in sediments can also potentially affect aquatic organisms. An understanding of the movement of contaminants into and from sediments is an important factor in predicting their long-term fate and effects in the aquatic environment.

In an effort to understand the biological significance of contaminants in sediments, the Ministry has developed an ecosystem approach for assessing sediments. This involves investigation of the physical, chemical and biological aspects of sediment contamination. Physical studies provide information on the type of sediment, while chemical investigation provides information on contaminant levels in bottom water, sediments and the aquatic biota that inhabit sediments, including the bottom-feeding predators. The biological component can provide indications as to fate and movement of contaminants in biological compartments and their effects on the organisms. The latter are often determined at the community or population level rather than effects on individuals.

In order to determine the major sources of contaminants, the study sought to establish the extent of contamination of the sediments through measurement of the sediment concentrations of metals, organochlorine pesticides, PCBs, PAHs, and chlorinated aromatics. Concentrations of these were also determined in the overlying water and resident biota (benthic invertebrates and fish) in order to assess the nature and extent of contaminant movement from the sediments, and to identify whether contaminants in sediments were adversely affecting aquatic organisms.

2. METHODS

In 1987, six stations were surveyed along Canagagigue Creek by the Aquatic Biology Section of the Water Resources Branch as part of its In-Place Pollutants Program. The stations were located upstream, at, and downstream of the Town of Elmira (Figure 1). Station 0001 was located in the town of Elmira but upstream of the industrial and sewage treatment sites and served as the control. Station 0002 was located downstream of the industrial complex that included the Uniroyal Chemical plant, the largest industrial employer in the area. The plant discharges only once-through cooling water and storm water from yard access directly to the creek. Process effluents are pretreated and discharged to the Elmira STP (OMOE 1989). Station 0006 was located immediately downstream of the Elmira Sewage Treatment Plant (STP), while station 0003 was situated approximately 100 meters downstream of station 0006. The sewage treatment plant discharges both domestic sewage and industrial effluents after secondary (biological) treatment. The remaining stations were located further downstream. Station 0004 was situated approximately 1.7 km downstream of the STP while station 0005 was located approximately 5.5 km downstream of the STP.

The study components included: surficial sediment chemistry (top 5 cm), bottom water chemistry, contaminant levels in benthic invertebrates (oligochaetes and chironomids) and bottom-dwelling fish, and benthic enumeration studies. In addition, the fine-sediment fraction (<63 μ diameter) was analyzed using an operationally defined sequential extraction scheme to determine the distribution of metals in the various geochemical phases (Persaud *et al.* 1987).

Bottom-water samples were collected by hand on the last day of each field survey. Water temperature, dissolved oxygen, and pH were measured and the sample was properly preserved according to the type of analysis required and submitted to the MOE laboratory. Samples were analyzed for nutrients, ions, metals, PCBs, organochlorine pesticides and chlorinated aromatics.

Sediment was collected by shovel. The top 5 cm from each of three samples were composited and placed in sample jars. Most physical measurements were carried out in the field in accordance with the methods described in Persaud *et al.* (1987) and included sediment pH, redox potential, bottom current, and sampling depth. Sediments were maintained at 4 C until analyzed.

Chemical analyses on sediment and bottom water were carried out in the MOE laboratory in

accordance with procedures described in OMOE (1983). Sediments and bottom water were analyzed for nutrients, metals, PCBs and pesticides, PAHs, chlorinated aromatics, and sediment particle size.

Benthic organisms for contaminant analysis were also collected by shovel. A minimum of 2 gms of the most abundant organism was collected at each station for inorganic contaminant analysis, wrapped in plastic and immediately frozen. An additional 4-5 gms were collected for organic contaminant analysis, wrapped in hexane rinsed foil and frozen. These were analyzed for PCBs and pesticides, PAHs and chlorinated aromatics as well as percent lipid content and ash. The percent ash was used to correct for gut content in determining tissue concentrations. Analyses were carried out by consultant laboratories according to the methodologies described in Persaud *et al.* (1987) and OceanChem (1988).

The most abundant bottom-dwelling fish (longnose dace, emerald shiners, rainbow darters and white suckers) were collected in an effort to gain an understanding of contaminant transfer between the various compartments (e.g., sediments, benthos, water, fish). Fish (approximately 6-10 cm total body length) were collected by seine net and a minimum of 15 fish were collected at each station for tissue analysis. Fish from each station were grouped by species, age and length. The analyses were the same as those for benthic invertebrates.

A total of 5 replicate samples for benthic invertebrate community analysis were collected at each station using a stainless steel Ponar grab sampler (22.9 cm.x 22.9 cm (9" x 9")). Samples were field washed using a U.S. 30 mesh (595 um) sieve and the residue was preserved in 5-10% neutralized (with borax) formalin solution. Samples were sorted under a dissecting microscope. The densities of organisms were averaged over the total number of replicates and the replicate closest to the mean values was chosen for detailed identification of the organisms present. The remaining four samples were set aside for biomass determination.

Biomass estimates were calculated as preserved wet weight of organisms. Samples were blotted dry on filter paper to remove surface moisture and were immediately weighed to the nearest 0.1 mg on a Mettler H20T balance. The results were averaged over the number of replicate samples and the mean value has been presented in the tables. A correction factor of 10% has been added to the total preserved weight to attain the total live wet weight. Studies by Wiederholm and Eriksson (1977) and Landahl & Nagell (1978) have shown that on average a 10% weight loss occurs in preserved specimens due primarily to differences in densities between ethanol and water.

Laboratory sediment bioassay experiments were conducted on material collected from Canagagigue Creek in the area of the Elmira STP on October 26, 1987. One sediment sample was collected per station from all 6 stations shown in Figure 1.

Sediments were transported to the MOE Rexdale laboratories, where they were stored at 4° C. Part of the sediments collected were used for analysis of the same parameters measured in July. On January 11, 1988, the sediments were sieved through a 3 mm mesh sieve prior to use in the bioassay to remove large particles and debris as well as homogenize the sediment. A total of 200 ml of sieved sediment was placed in a 1 l mason jar to which 800 ml of dechlorinated tap water was added. Six jars were filled for each station and the sediments were allowed to settle for 24 hrs. before aeration was started. After 1 hr of aeration, test animals were added to the jars. The six test jars for each station were divided into two groups of three jars each. Five fathead minnows (*Pimephales promelas*) were added to each of the three jars in the first group and five nymphs of the burrowing mayfly *Hexagenia limbata* were added to each of the three jars in the second group. The minnows used were cultured in the MOE Rexdale laboratory and were all 3 months of age. The mayflies were second year nymphs collected at Honey Harbour (an uncontaminated site) on Georgian Bay. Honey Harbour sediments were used for the experimental control.

The bioassay was run for a total of ten days in a controlled water bath at 20° C and was monitored daily during this time for any mortality, at which time any dead animals were removed. At the end of the ten day period the surviving animals were removed, frozen, and subsequently submitted for analysis of tissue contaminant levels. In order to obtain sufficient biomass for tissue analysis, the surviving mayflies from all three replicates were pooled. One replicate for fathead minnows (greatest number surviving) was selected for analysis.

3. RESULTS

3.1 Bottom Water

Results of the water quality analysis are provided in Tables 1 to 5. Canagagigue Creek can be characterized as a moderately shallow, hardwater stream (alkalinity ranged from 207.5 to 218 mg/l as $CaCO_3$, Table 1). The creek, at the time of sampling, was relatively turbid due to a moderately high suspended sediment load. The creek also carried a relatively high nutrient load, as levels of both carbon (as DOC) and nitrogen (as TKN) were moderately high. A reduction in the particulate load was observed at station 0005, the furthest downstream station, and shows that deposition of suspended material occurs in the lower reaches of the creek.

Significant increases in conductivity, phosphorus, sodium, chloride, sulphate, ammonium and nitrite were noted below station 0006 (Table 1). These confirmed the conclusions of an earlier Environment Canada survey of Canagagigue Creek (Carey *et al.* 1983) which found elevated levels of all of these parameters downstream of the Elmira STP. Conductivity increased from 516 umho/cm at station 0001 to 643 umho/cm at station 0002, below the Uniroyal Chemical Site, and increased further below the STP to 1700 umho/cm. High levels persisted as far downstream as station 0004, and elevated levels were still apparent at station 0005. Phosphorus levels increased from 0.156 mg/l at the control (station 0001) to a high of 0.250 mg/l at station 0003. Levels of sodium were 23 times higher below the STP and ca. 2 km. downstream (station 0004) were still 20 times higher (198 mg/l). Chloride and sulphate increased 8 and 10 times respectively at stations 0006 and 0003. In all cases, only minor differences were found between concentrations at station 0006 and 0003. Concentrations of all the above parameters were considerably lower at station 0005, but had not returned to upstream levels.

Ammonium levels increased by nearly 70 times at station 0002, and was the only parameter to show a major increase below the Uniroyal Site. A general increase in pH also occurred at station 0002 and higher pH persisted downstream through station 0005.

Metals data were generally available only for station 0001 (Table 2). The Environment Canada survey found downstream levels to be similar to upstream levels and these parameters were not analyzed except for mercury and arsenic. The data for Hg and As show that no detectable levels of either were recorded at any of the stations.

Levels of organics were below detection limits except for g-BHC hexachlorocyclohexane (Tables 3 and 4). Concentrations increased at station 0002 to 14 ng/l, and then increased 4-fold to 45 ng/l below the STP. No other organic compounds were present at detectable levels in the water column.

Carey *et al.* (1983) noted increased levels of chlorophenols downstream of the Elmira STP and concluded that some, at least, originated in the STP, while others more likely originated as groundwater seepage from the chemical waste disposal area just upstream of the STP. Only a very slight increase in 245 trichlorophenol (TCP) was noted at station 0002 during this survey (Table 5), but it also suggests that the disposal site and not the STP is the main source of this contaminant. A larger increase was noted in the levels of 246 TCP at station 0002. This compound has previously been linked to the STP effluent discharge (Carey *et al.* 1983).

3.2 Sediment

3.2.1 Physical Characteristics

Results of the sediment analyses are presented in Tables 6 to 12. Grain size analysis shows that sediments in Canagagigue Creek were mainly a sand-silt mixture (Table 6) with sand the dominant constituent at stations 0001, 0004 and 0005, while silt dominated at stations 0002, 0006 and 0003. Regardless of the higher sand content, sediment organic content as measured by TOC (Table 7) was high at all stations and was in fact highest at station 0003. Solvent extractables, which were lowest at station 0003, do not appear to contribute to the organic content. However, discharge from the sewage treatment plant may be a contributing factor to the higher levels of organic carbon at station 0003. Silt predominated at downstream stations which could account for the higher organic content at these stations, though contribution from the STP is still likely to be substantial. Seasonal changes indicate a tendency towards reduction of silt and clay and an increase in sand content in the fall, likely due to increased discharge (Carey *et al.* 1983) removing some of the finer material.

Sediment organic content in the spring was lower in the upstream areas than at stations 0003, 0004, and 0005, despite a high silt content. Organic content increased 2-fold at upstream stations in the fall, while levels at station 0003 decreased. The

seasonal differences suggest not only discharge related changes in sediment organic content, but also spatial variability in accumulation of organic matter. As the volume of discharge changes in streams, the flow dynamics are also altered, resulting in changes in depositional and erosional patterns. Higher accumulation would likely occur in depressions in the stream bottom, and makes comparison of different areas difficult.

Sediment oils and grease were very high at both stations 0001 and 0002 in the fall and suggest these areas were depositional zones subject to accumulation of suspended matter (Table 7). The 50% increase in solvent extractable levels at station 0002 suggests an additional contribution to sediment levels, possibly through losses from the Uniroyal yard, that are contributing to the already high sediment levels. No significant contribution was apparent from the STP during either sampling period.

3.2.2 Metals

Sediment concentrations of metals were at or below the Lowest Effect Level of the draft Sediment Quality Guidelines (Persaud *et al.* 1990) at all stations. Some longitudinal variation in concentrations was noted, primarily as increased sediment concentrations of many metals below stations 0002 and 0006 (Table 7). Seasonal variation was generally minor, and sediment metal levels fluctuated less than sediment TOC (Figure 2). In general, sediment metal levels in the spring correlated poorly with sediment organic matter, as measured by TOC, and only nickel levels appeared related to levels of organic carbon (Table 26). Much higher correlations were obtained between sediment particle size, namely the silt fraction, and metal levels, suggesting that metals were being deposited with the silt fraction, but that the silt did not comprise most of the organic fraction. It is possible that the organic material was comprised mainly of coarse organic matter representing generalized inputs from the watershed, and not a particular source. Levels in the fall correlated somewhat better, and significant correlations were obtained for a small number of metals (e.g. Fe, As, Al and Ni) and sediment TOC. The suggestion from both surveys is that sediment metals are not accumulated solely in conjunction with the organic fraction of the sediments. This is consistent with the observations noted in an earlier report on Canagagigue Creek by Environment Canada (Carey *et al.* 1983), which found little variation in metal levels throughout the stream.

During the spring survey, metal levels in the sediments appeared to vary only slightly between stations. Sediment concentrations at the control (station 0001) differed little from concentrations at stations 0006 and 0003 (Table 7; Figure 2). The only major increases were noted for zinc and manganese at stations 0004 and 0005, most likely as a result of accumulation of finer sediments in this area. Differences in sediment metal levels were slightly more pronounced in the fall, though the only change was a decrease in the upstream levels of Cr and Hg from those in the spring. Concentrations of other metals did not show any significant seasonal change.

Lead was the only metal in sediments that was significantly correlated with levels of solvent extractables. The implications are that this metal is either accumulated/ attracted by sediment oils and grease, or, more likely, is deposited within this matrix.

3.2.3 Geochemical Fractionation

Metals will often bind preferentially to different components of the sediment. The sequential extraction scheme is an operationally defined process that separates the various components in the fine-particle (<63 μ) fraction. The concentration of metals can be measured in each of the following geochemical phases:

IW - Interstitial Water
F1 - Cation Exchangeable Fraction
F2 - Easily Reducible or Carbonate Bound
F3 - Organic Complex
F4 - Fe/Mn Oxide Fraction
Res- Residual Fraction

The significance of each fraction is discussed in Persaud *et al.* (1987) and Tessier (1979). The results of the geochemical extraction procedure are presented in Table 8 and Figures 5 through 14.

The majority of the metals in the sediments appear to be associated with the more resistant fractions of the sediment, and, as such, probably represent background levels of these metals. At all stations, most of the metals were associated primarily with the F4 and Residual fractions, with only minor amounts in the IW to F3 fractions. However, there were some exceptions.

Andrews (1988) observed the movement of zinc in sediment fractions over time and noted that increased residence time leads to an increase in the residual fraction as the metal moves through the

less tightly bound fractions. Evans *et al.* (1988) suggested a similar movement of cobalt in sediments. The presence of higher metal levels in the IW to F3 fractions, relative to levels in the F4 and Residual fractions, suggests that the origin of the metal concentrations in the sediment is comparatively recent. Higher concentrations in the IW to F3 fractions also has implications for bioaccumulation of metals and this is discussed in the next section.

Levels of aluminum, arsenic, and iron showed little variation among sediment fractions in the study area. In all cases, levels were highest in the F4 and Residual fractions and only minor amounts were present in the IW to F3 fractions. The data suggests that little input of these metals is occurring in the study area and that sediment concentrations appear to be due mainly to sources in the watershed.

Chromium in sediments increased significantly in the F3 fraction beginning at station 0002, with a peak at station 0006. The distribution suggests that additional Cr is being deposited from sources at station 0002 and 0006.

Copper increased mainly in the F3 fraction at, and downstream of, station 0002, while levels in the F4 fraction decreased. Since copper concentrations in sediments did not vary significantly among stations, the changes in the amounts held in the various fractions may be due to mobilization of Cu in the sediments and adsorption to different sediment fractions. Calmano *et al.* (1988) suggest that desorption of metals in sediments may occur, with subsequent binding at a relatively more stable level, on other sediment surfaces. Cu was found in their study to form relatively stable surface complexes with organic matter and may reflect a general affinity of copper for organic particles.

Cadmium levels underwent minor fluctuations among stations, with the largest increases occurring in the F4 fraction. Changes in sediment levels therefore could not be related to any specific source in the watershed.

Lead increased mainly in the F4 fraction, with the highest levels at station 0002 and 0006. Levels in the other fractions showed very little change.

Manganese appears to be held primarily in the F2 and F3 fractions and this relationship remained relatively unchanged throughout the study area.

Nickel was present in all of the solid sediment fractions (F1 to F4) and levels fluctuated only slightly among stations. Levels were actually lower at stations 0002, 0006 and 0003. Since sediment Ni levels were significantly correlated with TOC, it appears that Ni also originates from general sources in the watershed, rather than specific point sources, and accumulates with organic matter.

Zinc also varied little over the study area, though the relative distribution among sediment fractions changed, with relatively more Zn in the F4 fraction at and downstream of station 0002, and less in the Residual fraction.

3.2.4 Organic Compounds

Sediment concentrations of most organic contaminants were generally below detection limits. Major exceptions were the high concentrations of pp-DDT and its metabolites pp-DDD and pp-DDE (Table 9). DDT in sediments increased at station 0002, and then increased further to very high levels at station 0006 (Figure 4). Sediment concentrations of pp-DDT exceeded the Severe Effect Level of the draft Sediment Quality Guidelines at station 0006. The Severe Effect Level is the sediment concentration at which a toxic effect would be expected that would affect all but the most tolerant benthic organisms (Persaud *et al.* 1990). Concentrations gradually decreased downstream, though even at station 0005, sediment concentrations of pp-DDD, pp-DDT and pp-DDE exceeded the Lowest Effect Level of the Sediment Quality Guidelines. The Lowest Effect Level is the sediment concentration that can affect some sensitive benthic organisms. The indications are that the Uniroyal Plant is one source of input of DDT at station 0002, but that the STP outfall located above station 0006 has been, or is, a much larger source of DDT. Since process water from the Uniroyal Plant is routed through the STP, it is apparent that the STP is not entirely effective at removing these contaminants. Levels of DDT were lower in the fall and suggest that contamination of sediments is not evenly distributed but that deposition of the compounds has occurred erratically, most likely as a function of the river's flow regime.

Levels of PAH in sediments ranged from below detection limits to a high of 540 ppb for fluoranthene at station 0002 (Table 10). Levels of all

PAHs except dibenzo[a,h]anthracene, naphthalene, acenaphthene and fluorene increased at station 0002 relative to station 0001, and in most cases levels were highest at this station. The largest increases were for fluoranthene, pyrene, chrysene, benzo[k]fluoranthene, benzo[b]fluorene and benzo[a]anthracene, levels of which were 5-fold higher at station 0002 than at station 0001 (Figures 3a and 3b). Levels at station 0006 were generally slightly lower than at station 0002, and sediment concentrations returned to near upstream levels at station 0005. The majority of the PAH compounds seem to originate from a source near station 0002.

Levels of most other organics were below detection limits and no significant sediment accumulation of these organic compounds is apparent (Table 11). Many of these compounds are relatively soluble in water, and a number are also volatile and would not be expected to persist for any length of time in sediments.

The slight increase in levels of some of the chlorophenols that was noted in the water column did not translate into higher sediment concentrations (Table 12). Levels of all were below detection limits in the sediments.

3.3 Aquatic Biota Contaminant Analysis

3.3.1 Benthic Invertebrates

The geochemical distribution of metals in the sediment can directly influence the availability of the metals to aquatic organisms. Studies (Luoma 1983; Smock 1983) have suggested that 80 to 85% of an organisms body burden may be acquired by adsorption of metals through the integument or cuticle (Knowlton *et al.* 1983) and that the free ion concentration in the interstitial water is usually the most available phase. However, sediment-bound metals may contribute significantly to an organisms body burden, depending on the metal, as well as on the availability from the sediments. While the efficiency of uptake has been shown to be much greater from the water phase, as compared to efficiency of uptake from ingested matter (Luoma 1989), the much larger sediment concentrations often means that ingestion may contribute significantly to organism tissue concentrations of certain metals under certain conditions.

Sorption of contaminants by sediments and desorption to the water phase are believed to be continuous exchange processes (Stumm & Morgan 1981). Levels of metals and organic compounds available to biota from the water phase (i.e., interstitial water) would therefore depend on levels available in the solid phases of the sediments. As such, in areas of contaminated sediment, even minute concentrations in the interstitial water or bottom water could contribute significantly to an organism's body burden through a more or less continuous availability of the contaminant. This depends mainly on ease of release from the solid fractions to the interstitial water, which appears to be the main medium of uptake by aquatic organisms (Luoma 1983; McElroy *et al.* 1989).

Metal accumulation by benthic biota appears to be a complex process that cannot be described by any simple relationship between sediment or water concentrations, and tissue residues. Accumulation is affected by a large number of factors, and tissue levels are the sum of adsorption from the water, desorption from the sediment and absorption from ingested matter. Depending on sediment characteristics, the amount contributed from each of these processes can vary. It is generally recognized, however, that the most efficient means of uptake is through adsorption of free ions from the water column or those desorbed from the sediments. Desorption of metals is itself a complex relationship affected by a number of physical and chemical factors such as pH, redox potential (Eh), organic matter, Fe/Mn oxides, clay minerals, and particle size.

Correlation analysis (Spearman Rank Correlation) between tissue metal levels and the amounts held in the various geochemical fractions yielded poor correlations between body burdens and all sediment fractions (Table 27). Metals held in the solid fractions (F1 to F4) are generally considered to be potentially available to aquatic organisms (Persaud *et al.* 1987). Availability decreases somewhat from the F1 to the F4 fraction as binding strength to the sediments increases and potential for release to the water (mainly the interstitial water) decreases. Metals bound to the F4 fraction (Fe/Mn oxides/hydroxides) are usually unavailable except under reducing conditions (Stumm & Morgan 1981). Metals held in the organic fraction, though potentially available, can also be tightly bound and may not be easily removed under the gut conditions of most benthic organisms (Luoma 1983). Nevertheless, metals held in the F1 to F3 fractions are potentially the most available to benthic organisms, since these are the most readily extractable.

Metals held in the residual fraction are usually not available to benthic organisms nor are they readily released to the water. These are the most tightly held metals, since they are bound within the crystal lattices of minerals (clays etc) and are not available under natural conditions.

Since, in the case of metals, 15-20% of an organism's body burden can be acquired through ingestion of contaminated sediments, the presence of contaminants in the more readily available fractions could serve to facilitate uptake and tissue concentration by means of digestive processes. The presence of metals in these fractions could also serve to increase the availability of these metals in the interstitial water.

Biota-sediment concentration ratios are presented in Table 12. Since the biota levels are a factor of uptake from both sediment and the water column (though the contribution from the latter is likely to be minor in the case of sediment in-fauna) the term bioconcentration has been avoided. For sediment in-fauna this ratio can be used as an expression of the availability of contaminants from the sediments. A high ratio denotes that levels in organism tissue were higher than levels in the sediments and suggests that availability from these sediments is high. It must be borne in mind, however, that a high concentration ratio does not necessarily imply high tissue levels but merely measures tissue levels relative to sediment levels.

In general, benthic organism tissue metal concentrations correlated poorly with sediment levels, either in bulk sediments or the geochemical fractions. The most significant correlations were actually obtained for some of the metals between the various geochemical fractions (Table 25). These correlations may therefore actually describe the most likely sorption - desorption pathways for metals in the sediments. Studies by Andrews (1988) and Evans *et al.* (1988) have suggested that, as sediments age, there is a net movement of metals from the more easily exchangeable fractions to the more tightly held fractions, and these statistical relationships may be describing this movement. Tessier *et al.* (1984) found similar results with metals and benthic organisms.

Benthic organism tissue concentrations could not be related to levels of contaminants in the water column, in part because levels in the latter were generally very low. Other studies have indicated that metals tend to bind to organic matter and iron/manganese oxides in the water column and that most of the contaminant load is rapidly transported to the sediments (Sigg *et al.* 1988).

It has yet to be proven that no differences exist in contaminant uptake among different species and therefore, only the tissue levels in oligochaetes, which were the only organisms consistently found at all stations, are compared. Since some of the organisms listed in the tables spend most of their aquatic life history in the water column (e.g., dragonflies and some leeches) only oligochaetes can be considered as truly sediment-dwelling species and the only ones exposed most fully to sediment-bound contaminants.

Invertebrate tissue residues were generally lower than sediment concentrations for most metals when calculated on a wet weight basis (Table 14). However, tissue residues were most often highest at station 0002. The lack of any significant correlations between sediment fractions and tissue residues, and the strong correlations between sediment particle size, and, to a lesser extent, sediment organic matter and some metals suggests that availability is strongly affected by sediment organic content. As shown in Table 12, only a few of the metals were concentrated in benthic organism tissues to higher concentrations than in the sediments.

Levels of arsenic in invertebrate tissues, when calculated on a dry weight basis and corrected for gut contents, were significantly higher than sediment levels at all stations (Figure 15a). Total tissue concentrations differed only slightly between stations and suggests that availability from the sediments did not differ significantly. However, no relationship between bulk sediment concentrations and tissue levels could be obtained (Table 27). Tissue-sediment concentration ratios were greater than 3 at the control and increased to nearly 9 at station 0003 (Table 13). Arsenic was apparently being concentrated to much higher levels in tissues downstream of the STP, even though sediment levels were the same, or lower than, upstream levels.

Tissue residues of zinc also increased significantly in relation to sediment levels at locations downstream of the control. Total tissue concentrations were significantly higher at station 0002 (approximately 3.5 times higher than at station 0001) and returned to near upstream levels at stations further downstream. Tissue concentrations calculated on a dry weight basis and corrected for gut contents increased to nearly 4 times the

sediment levels at station 0002 before dropping to upstream levels at station 0004. Since bulk sediment levels had not increased significantly at station 0002 as compared to station 0001, this increase seems to be due mainly to greater availability from the sediments.

Tissue lead levels also increased at station 0002 (Figure 15d), as did levels of copper (Figure 15c) and cadmium (Figure 15b). The increase in tissue residues was disproportionately higher than the increase in sediment levels at this station. Lead levels in tissues at station 0002 were approximately 2 times higher than at station 0001 and suggests that sources at station 0002 are contributing to higher tissue lead levels. Since tissue lead levels also increased in all fish species (see next section), lead levels in the water column, rather than sediment bound lead, may be the principal source to the aquatic organisms. In the case of copper and cadmium, sediment levels were actually higher at stations 0003 and 0004 (Figures 15c and 15b). Tissue levels of all three metals, however, were lower at these two stations, indicating that the metals were not as readily available from the sediments as at station 0002. Major increases in concentrations of all three metals occurred in the F4 fraction, which should theoretically be less available to benthic organisms than the other fractions. For example, higher concentrations of lead were available in the F3 and F2 fractions at station 0006, but tissue levels were much lower than at station 0002.

Mercury levels in tissues did not vary greatly, though organisms downstream (0003, 0004 and 0005) did have higher tissue residues than those upstream (Figure 18). Tissue-sediment concentration ratios were highest at station 0001 and 0003 (Table 13). Mercury concentrations in sediments did not vary greatly between stations, and benthic organism tissue residues appear to be related more to the relative availability from the sediments than to actual sediment concentrations.

Tissue residues of the remaining metals (Al, Fe, Mn and Ni) were below sediment levels, though most did show a slight increase in organisms downstream (Table 14). In most cases, downstream levels were not significantly different from the upstream control.

Levels of organic compounds in oligochaetes were generally below detection limits, though higher levels did occur in some isolated instances, mainly in levels of DDT and metabolites (Table 15). However, tissue levels of these were still very low considering the very high sediment levels and suggests that these are generally unavailable to benthic organisms.

Tissue levels of other organics were below detection limits (Table 16) and indicate no accumulation of these compounds has occurred.

Tissue levels of some of the chlorophenols, which were detected in water but not in sediments, were also detected in oligochaetes at some stations. Levels of 345 and 246 trichlorophenol were above detection limits at stations 0002 and 0006, as were tissue levels of pentachlorophenol (PCP) (Table 17). Levels further downstream were generally below detection limits. The presence of chlorophenols in both the water and oligochaetes suggests that water, and not sediment concentrations, are the primary route of uptake. Detectable levels appear to be confined to the area at and below the Uniroyal site.

3.3.2 Bottom-Dwelling Fish

Comparison of tissue residues in fish was considerably more difficult due to the variety of species tested in the river. No one species of fish was caught at all stations and, though all were bottom feeders, they varied in their method of feeding. Therefore, only similar species are compared, though a general overview is also attempted.

White suckers generally accumulated higher copper levels than the other species (Table 18). While these were caught only at downstream sites, tissue levels were higher than in other fish caught at the same locations. Shiners and dace also showed a slight increase in Cu levels downstream. The higher levels in suckers may be related to their feeding habit, since these fish generally feed on bottom dwelling organisms, disturbing the sediments as they feed.

Tissue levels of chromium among the three species were contradictory. The tissue levels in dace increased slightly at downstream locations, while levels in shiners decreased. Levels in suckers did not appear to change among stations, though no upstream control was available for this species. Nevertheless, Cr does not seem to be highly available to fish from the sediments.

Considerable variation in tissue levels of mercury was also noted among the three species.

While dace at station 0005 had slightly higher levels of Hg than at the control (station 0001), shiners showed considerably higher levels at all downstream locations. Suckers had consistently lower levels than either the shiners or the dace. Evidently mercury is being accumulated in the tissues of some species of fish, though the origins of the mercury are not clear. The higher levels in the shiner suggest the water column as the main source, rather than the sediments, though whether the levels in the water column are due to desorption from the sediments cannot be determined.

The highest cadmium levels were found in suckers at those stations closest to Elmira and decreased further downstream. Levels in the other two species yielded lower tissue levels in downstream fish than at the control. The data suggests that the contribution of sediments to the total cadmium tissue residues in fish is relatively minor.

Nearly all fish showed an increase in iron levels downstream of the control, though this could be due to uptake from the water rather than from the sediments. Sediment levels showed little variation in either bulk levels or in levels in the various geochemical fractions.

An increase in lead levels was noted in all species at downstream stations, with the highest levels occurring at station 0004 and 0005 in all fish.

Arsenic levels showed no pattern of increase similar to the benthic invertebrates. Tissue levels in fish caught at the control were similar to tissue levels in fish caught downstream and levels appeared to be highly variable, depending on the individual fish. For example, both the highest and lowest tissue concentrations were obtained from white suckers caught at station 0002.

Zinc was generally not accumulated to higher levels in any of the fish species downstream. The highest tissue levels were found in shiners, (this was the only species that showed any change in body burdens) and this fish was caught at station 0001.

Of the organochlorine pesticides and PCBs, a-BHC, endosulfan sulphate, pp-DDE and PCBs were detectable in tissues (Table 19). a-BHC and endosulfan sulphate were only detected in shiners at stations 0003 and 0004. Both compounds were below detection limits in the sediments and water column so that the specific source, water or sediments, cannot be determined. The literature does suggest that desorption from the sediments can be a significant route of uptake for organochlorine compounds.

Tissue levels of pp-DDE, a metabolic product of the breakdown of DDT and DDD were elevated to relatively high levels in shiners at stations 0006, 0003 and 0004. Levels of DDT and its metabolites were very high at station 0006 and remained high downstream to station 0004. Sediment pools, through desorption from the sediments as well as food chain transfer, may be a significant factor in the accumulation of pp-DDE by these fish. Suckers accumulated DDE only at station 0004. Tissue levels of pp-DDE, in general, were highest in those fish caught at stations 0002, 0006, 0003 and 0004. These elevated levels correspond to the highest sediment concentrations of DDT and related compounds in the creek. While some of the accumulated body burden may be due to ingestion of contaminated food items, the generally low levels in benthic organism tissues suggests that other routes of uptake play a significant role. The seasonal variation in sediment levels of these contaminants implies that considerable resuspension of sediments can occur. This has strong implications for water column organisms, since direct exposure of fish could be increased during these periods.

Both shiners and dace had higher tissue levels of PCBs at downstream locations, with the highest levels occurring at stations 0004 and 0005. Sediment levels were below detection limits at all stations and direct desorption from the sediments to the water would not likely be the main route of uptake of these compounds. The consumption of contaminated prey (some accumulation of PCBs was noted in oligochaetes) may be a significant factor.

Accumulation of chlorinated aromatics was generally low and limited to certain individual fish (Table 20). For example, one shiner caught at station 0004 had elevated levels of 135 trichlorobenzene, HCB and 1234 tetrachlorobenzene, while most others had tissue levels below detection limits.

Fish, like the invertebrates, also accumulated pentachlorophenol (PCP) and 246 trichlorophenol (TCP) in their tissues (Table 21). PCP was generally accumulated by all fish, though levels in fish caught upstream were as high or higher than fish downstream. PCP accumulation appears to be consistent throughout this section of the river. Whether this is from the sediments or

water column is difficult to determine since levels in both were below detection limits.

Accumulation of contaminants by fish species could not be related to sediment levels of contaminants. In many cases, the tissue levels of metals in fish were similar or lower than the levels in benthic invertebrates. For comparative purposes only, all fish data were grouped and the mean tissue concentrations were calculated for each station. These were compared with the invertebrate (oligochaete) tissue levels and the results are shown in Figure 16. Tissue levels of mercury and zinc were generally slightly higher in the fish than the oligochaetes. The higher accumulation of these metals by fish suggests that food sources may be a significant route of uptake, in addition to adsorption from the water. Levels of Cu, Cr and Ni were similar for both fish and invertebrates and suggests that levels in the water column may be a significant path of uptake for these metals. The lower levels of the remaining metals in fish, as opposed to invertebrates, suggests that sediment contaminant concentrations can play a role in availability of metals to aquatic organisms.

Fish however, accumulated much higher tissue concentrations of the organic compound pp-DDE than did invertebrates. The most likely mechanism of accumulation for this compound, as well as the metals, is through desorption from the sediment to interstitial water. Studies have shown that levels of contaminants in the interstitial water are usually more similar to sediment concentrations than to water column concentrations (McElroy *et al.* 1989). In addition, desorption from the solid sediment fractions to the interstitial water could provide a more constant supply of contaminants than the water column, which would depend primarily on autochthonous input. Seasonal changes in discharge appear to influence sediment deposition and hence, are also likely to affect resuspension, with increases likely during periods of peak flow. This could strongly influence the availability of these compounds in the water column. Such differences in exposure could readily account for differences in uptake patterns between these two groups of organisms.

3.4 Sediment Bioassay

The results of the acute toxicity bioassay are presented below. The percent mortality over the ten day period is shown for both mayflies and fathead minnows.

Station	Fathead Minnows	Mayflies
0001	0	0
0002	100	9.1
0006	0	0
0003	0	6.7
0004	0	0
0005	0	6.7
Control	0	0

Percent mortality can be compared with a previously determined "safe value" of 20%. Where the results exceed this level, significant mortality has occurred. Mortality in the control must not exceed 10% for the bioassay to be considered valid. The results show that the sediments were not acutely toxic to mayflies at any of the stations over the ten day test period. The highest mortality among the mayflies was observed at station 0002 but was low and reached only 9%. Mortality reached 6.7% at both stations 0003 and 0005, and this can also be considered low and could be attributable to other causes. No mortality was observed at any of the other stations.

In contrast to the mayflies, fathead minnows exhibited very high mortality in sediments from station 0002. This was the only sediment in which mortality was observed in these organisms and occurred at the 100% level. Sediments from station 0002 therefore appear to be highly toxic to fathead minnows.

No cause for the high level of mortality is immediately apparent. The only sediment parameters that were elevated at station 0002 in October of 1987 were levels of DDT and its metabolites (Table 9) and sediment oils and grease (Table 7). Since levels of the latter were also high at station 0001, where no mortality was observed, this does not appear to be the major cause. Disturbance of the sediments may have resulted in greater availability of the DDT compounds in the water, though the low mortality in the mayflies suggests that this may also have been low.

Tissue analysis of the organisms still surviving at the end of the ten day period show low accumulation of most organic compounds in mayflies in station 0002 sediments. Tissue levels of DDE and DDD were highest in mayflies kept in station 0002 sediments (Table 23), and indicates that accumulation from the sediments did occur. Fatheads generally accumulated higher tissue levels of DDD and DDE from downstream sediments

than did mayflies and may suggest that high levels of these compounds were available to fatheads at station 0002. This is consistent with the field data, which also showed higher tissue levels in fish than in invertebrates.

Tissue levels of aldrin were also elevated in mayflies kept in station 0002 sediments and were approximately 8 times higher than in mayflies at other downstream locations. Fatheads accumulated high levels of aldrin only in those fish kept in station 0004 sediments.

Levels of chlorinated organics in mayflies and fatheads kept in the experimental sediments were not significantly different than levels in those kept in the control sediments (Table 24). Both mayflies and fathead minnows had detectable tissue concentrations of some of the chlorinated aromatics (135-trichlorobenzene, 123 trichlorobenzene and hexachlorobutadiene). Levels in the control sediment animals were not significantly different from those kept in the creek sediments and these levels likely represent the background body burdens of the test population.

Mercury and cadmium were the only metals that were accumulated in mayfly tissues to higher levels in the experimentals than in the controls (Table 22). Levels of mercury in mayflies maintained in station 0002 and 0006 sediments were approximately 2 times higher than in those kept in station 0001 sediments or the control sediments. The highest tissue levels were recorded in station 0003 sediments, where levels were nearly 10-fold higher. Tissue levels in mayflies in station 0005 sediment were similar to mayflies kept in upstream and control sediment. Tissue levels of cadmium in the experimental animals did not differ greatly from the controls except for station 0006, where one sample had levels approximately 50% higher. No other metals in mayflies exposed to creek sediments were accumulated to levels higher than in the control animals.

Mercury did not appear to be accumulated by fathead minnows and levels in the experimental animals were similar to those in the controls (Table 22). Tissue levels of cadmium were higher in some of the experimentals. While levels in fatheads maintained in station 0001 sediments were higher than those in the controls, levels in those kept in station 0006 and 0003 sediment were approximately 30% higher still. Tissue levels of lead were also higher in those kept in station 0006 sediments, though levels at the other stations were similar to those in the control animals. Manganese levels were also elevated in most of the test fish, and only those kept in station 0003 sediments had levels similar to the control fish. The increased uptake of Mn at the other stations may be related to the relatively high levels of Mn that were present in the more available sediment fraction (F1 to F3), which under the test conditions may have become more available in the water column.

It appears from these data that only some of the metals and the DDT group of chemicals were concentrated by the test animals to levels higher than those in the control sediments. Levels in benthic invertebrates and fish collected in situ from the creek (see preceding section) were generally similar to the test results and suggests that the observed body burdens in the field populations were acquired under similar conditions of exposure and uptake. Temporal variation in flow could disturb the sediments and result in resuspension of this material. Under such conditions, the contaminants in the sediments may be more readily available for uptake by aquatic organisms, particularly the water column organisms such as fish.

3.5 Benthic Community Analysis

Results of the benthic analyses are presented in Tables 28 and 29. The benthic fauna at all stations was characterized by a predominance of oligochaetes and chironomids and throughout the study area the creek appears to be organically enriched. The oligochaete fauna at all stations was comprised mainly of *Limnodrilus hoffmeisteri* and *Tubifex tubifex*, both of which are common species in organically enriched areas (Brinkhurst & Kennedy 1965; Kennedy 1965). At all stations they comprised over 80% of the total benthic fauna (Figure 17). The predominance of this group of organisms could be directly related to the high organic content of the sediments.

Station 0001, located upstream of the industrial site in the town of Elmira, served as the control. Benthic diversity here was low and the *Limnodrilus hoffmeisteri* and *Tubifex tubifex* community dominated the fauna (Table 29). These formed 96% of the total density and 99% of the biomass (Table 28). The only other organism present in any significant density was *Chironomus* sp. Both *Chironomus* and the oligochaetes are

associated with fine organic sediments and their presence in such profusion in this area is most likely due to higher sediment organic levels (Buscemi 1966).

Station 0002 showed a significant increase in invertebrate density, the total number of organisms being slightly more than double the density at station 0001. This difference is apparently not directly related to the sediment organic levels which were very similar to station 0001.

Station 0006, located near the sewage treatment plant, yielded densities and biomass values close to those observed at station 0001. Despite the proximity of the STP, sediment organic levels were slightly lower at this station than at the preceding two stations. Again at this station, the sediment feeding species, comprised mainly of oligochaetes and chironomids, were the dominant forms. Station 0006 also had the highest sediment levels of DDT though this has apparently had no effect on the benthic fauna.

Located ca. 100 m downstream of the Sewage Treatment plant, station 0003 had the lowest overall density of organisms (Table --) which amounted to approximately half the density at station 0001. Biomass values however were only 25% of those at station 0001 indicating that the fauna, comprised almost entirely of oligochaetes (*Limnodrilus* spp.), grew to a smaller size than the worms at any of the other stations. Since sand comprised a large fraction of the substrate at this station, these changes in the physical environment could also affect the benthic community and contribute to both the lower density of organisms and the reduced size of the individuals. Johnson *et al.* (1987) found that sediment texture and organic content were the most important abiotic factors influencing the distribution of fine sediment feeders such as the oligochaetes. Contaminant levels in either the sediments or the water column do not appear to be the major factor since levels of most parameters were lower than at station 0006, which yielded a larger fauna. However, the possibility exists that, due to proximity to the STP outfall, full mixing of the water column had not occurred at station 0006 and that the effects observed are due to water column and not sediment effects.

While stations 0002, 0006 and 0003 were all located close to each other at the western end of Elmira, station 0004 was located approximately 2.5 km. downstream and well away from the town. The high organic levels of the sediments and the similarly high densities and biomass values at station 0004 indicate that a generally high level of enrichment is common for much of the lower reaches of Canagagigue Creek. This area of southern Ontario is under intensive use from agriculture, and has been for at least 100 years. Organic pollution from agricultural sources seems the most likely cause of the high density of fine sediment feeders such as *Limnodrilus* spp and *Tubifex tubifex*, not only at this station but throughout the lower stretches of the stream.

Located furthest downstream, station 0005 was similar to station 0004 though densities were considerably reduced. As at the upstream stations, the fauna was almost exclusively fine sediment feeders of which *Limnodrilus hoffmeisteri* was the most common. There appears to be no obvious cause of the lower density or biomass of organisms at this station since sediment organic and contaminant levels differed little from station 0004. The discontinuous nature of invertebrate distributions is presumed the major cause of this difference.

Canagagigue Creek, according to its benthic fauna, can be broadly categorised as organically enriched. The fauna at all stations was one typical of areas high in organic matter and was comprised mainly of the oligochaetes, of which *Limnodrilus hoffmeisteri* was the most common. Since the organic levels were high throughout the study area the indications are strong that agricultural activity in this area over the past 100 years or more has been the main cause of the organic input, since no specific source of this material was evident.

Beckett & Keyes (1983) note that toxic chemicals (mainly organic chemicals) exert a stress on a benthic community that is usually manifest as a reduction in both density and diversity of all the benthic groups. Winner *et al.* (1980) found similar results in relation to heavy metal contamination. The reduction in density and diversity at station 0003 is most likely due to the STP inflow which contributes higher levels of chloride, sulphate and ammonium to the water column. Effects of sediment contaminants were absent in Canagagigue Creek and the fauna responded in a manner typical of organically contaminated areas. It should be noted however that the fauna found in this study area is one that is often more tolerant of other contaminants as well (Chapman *et al.* 1982a, 1982b). The high levels of DDT and DDD at station 0006 and to a lesser degree, stations 0002 and 0003 also had little apparent effect, apparently due to

availability from the sediments.

Biomass

Changes in biomass mirror the changes in the density and diversity of benthic organisms as noted in the previous section (Table 28). The high biomass at station 0001 was concentrated in the oligochaetes which accounted for 99% of the total. Since this station served as the upstream control, these levels can be taken as typical of the creek. The high oligochaete biomass indicates that the stream is highly productive due to the input of organic matter. The high biomass also indicates that the available organic matter is readily utilized by the benthic organisms. Average weight of individual worms was $2.7x10^{-3}$ gms.

Both density of organisms and biomass were greater at station 0002 and oligochaetes formed 84% of the biomass. Individual weight of worms though was lower (mean weight = $1.8x10^{-3}$ gms) and indicated a more rapid growth due to the greater availability of food. Competition among an apparently expanding population is also a likely factor in the smaller size of the individuals.

Biomass was lower at station 0006 than at station 0002. A higher sand content than at the control is likely the main cause of the lower biomass and the smaller size of the individuals, which occurred despite the greater density of organisms. The more diverse fauna would also help to limit the growth of the worm population through competition for resources.

Station 0003, in a predominantly sandy area, had the lowest density and the smallest individual size of oligochaetes (mean weight = $1.2x10^{-3}$ gms). This can be directly attributed to the lower organic content of the sediments which would serve to severely limit the growth of the oligochaetes.

Stations 0004 and 0005 both had higher densities though individual weights were both approximately equal to those recorded at station 0002. The higher organic content of the sediments is readily transmitted to the oligochaete population and is apparent mainly as increased density of the population. The mean size of individual worms however was lower than at the upstream control.

Brinkhurst & Kennedy (1965) and Kennedy (1965) have noted that in relatively warmer waters such as shallow areas of stream and lakes, organic enrichment results in an increase in the reproductive rate of oligochaetes and that often the faster development rate of the individuals results in individuals of smaller size that reach reproductive age sooner than in unenriched populations. The addition of organic matter at the stations below the control appears to be having just such an effect in Canagagigue Creek.

4. DISCUSSION

The Uniroyal Ltd. chemical plant, located in the town of Elmira, is the site of a toxic waste disposal site at which numerous chemicals, among them dioxins, DDT, mercury, lead and cadmium, have been buried there for some time. No evidence of contamination of the surrounding soil has been found. The drums containing the waste were removed in late 1987. The plant has, in the past, produced a variety of specialty chemicals, among which are included a number of pesticides.

The data from this survey indicate that levels of DDT, some of the chlorophenols and a number of the PAHs were higher in the sediments downstream of station 0002, located near the Uniroyal site. Levels of some of the metals, while slightly elevated, were not significantly higher than upstream areas.

A far more noticeable impact on water and sediment quality could be ascertained below the Elmira Sewage Treatment Plant, located just upstream of station 0006. The sewage treatment plant effluent has apparently contributed to very much higher levels of sodium, chloride and fluoride as well as increases in suspended matter and conductivity in Canagagigue Creek. Probably due to the relatively low volume of flow, these high levels persist for a considerable distance downstream. Carey *et al.* (1983) observed that during low flows, the STP effluent can comprise up to 10% of the total stream flow. While levels had decreased by station 0005, at the downstream limit of the study area, these had not returned to upstream levels. Though data for metals was generally lacking, the STP effluent generally did not contribute to elevated levels of any of the organic compounds in the water column. The increased levels of chlorophenols appeared to be related more to sources near station 0002 than the STP.

Sediment particle size and organic matter content were highly variable, both among the different stations and at the same stations during

the different seasons. This variability most likely reflects variations in the flow regime of the river, which can fluctuate considerably from spring run-off maxima to summer minimum flows (Carey *et al.* 1983). The uneven distribution of fine sediments also indicates that different sections of the stream bed are subjected to different erosional forces at different times of the year, resulting in shifting pockets of accumulation.

The distribution of metals in the sediments underwent little change longitudinally, with upstream levels generally similar to downstream levels. Most of the variation could actually be accounted for by the changes in sediment type, specifically by changes in the silt content, and, to a lesser extent, changes in the organic matter content. The Elmira STP did not appear to contribute to sediment metal concentrations. The presence of most metals in the more resistant chemical fractions suggests that inputs are not recent and not from a local source. Andrews (1988) and Evans *et al.* (1988), in studies on the movement of zinc and cobalt respectively, have suggested that as sediments age the movement of metals is from the more easily exchangeable fractions to the more tightly held fractions. Since the distribution of most metals among the various sediment fractions changed only slightly, this suggests that recent or localized inputs were lacking. If metals had been deposited in the sediments from local sources, studies suggest they should have been present mainly in the F3 and other more readily exchangeable fractions, and less so in the residual fractions, at least in the areas that were close to the sources of input.

Organic contaminants were generally below detection limits, though a few parameters can be linked to local sources of input. Levels of DDT and its metabolites were elevated below the Uniroyal site and increased again to very high levels at station 0006. Levels of ppDDT at station 0006 exceeded the Severe Effect Level of the Sediment Quality Guidelines and could be expected to have a pronounced effect on the benthic community. Since this site was below both the Uniroyal Site and the STP, the exact origin of these compounds in the sediments is uncertain, though the main impact appear due to the STP. Levels decreased with distance downstream, but nevertheless show that stream sediments contain high levels of these pesticides. This is not too surprising, since the affinity of these highly stable compounds for sediment organic matter has been well demonstrated (e.g. Oliver & Charlton 1984; Smith *et al.* 1988).

Sediment concentrations of a number of PAH compounds were higher below the Uniroyal plant (station 0002). The largest increase was in those PAHs that are, for the most part, anthropogenic in origin, with the most likely source being surface runoff from the urbanized and industrialized areas (Wakeham *et al.* 1980). Levels increased significantly at station 0002, and, at 3.16 µg/g total PAH, exceeded the Lowest Effect Level Guidelines of the draft Sediment Quality Guidelines (Persaud *et al.* 1990). Concentrations of total PAH at station 0006 also slightly exceeded these guidelines, suggesting that some effect on sensitive benthic organisms could be expected.

Concentrations of other organic compounds were generally below detection limits. The presence of chlorophenols in the water column, as noted earlier, did not translate into higher levels in the sediments. Sediments therefore do not appear to be a major reservoir for chlorophenols and this may be due to the relatively greater solubility of these compounds in water or a more rapid metabolism and breakdown in sediments.

Geochemical fractionation suggests that many of the sediment metals originate in the watershed and are not related to specific sources. However, it must be borne in mind that the geochemical fractionation of the sediments by the sequential extraction procedure merely measures the sediment bound metals in operationally defined extractable phases and these may not necessarily reflect the natural distribution of metals in sediments. Therefore, while the extraction procedure can be useful in providing an indication of the distribution of metals in various sediment phases, these are not necessarily indicative of the available concentrations of these metals to either the interstitial water of biota.

Levels of contaminants in aquatic organisms were generally low. Tissue metal concentrations in benthic invertebrates, calculated on a dry weight basis and corrected for gut contents, showed that mercury copper, cadmium, zinc and arsenic levels generally exceeded sediment levels. With the exception of Cd, tissue levels exceeded sediment levels at both upstream and downstream stations. For all metals except mercury, the concentrations in tissues relative to sediments increased at station 0002. The ratio of tissue levels to sediment levels was highest at station 0003, below the Elmira STP and may reflect the additional inputs from this source. There is no data available to verify whether

losses of metals occur from the STP.

Tissue levels of contaminants in benthic invertebrates could not be related to levels in the water column or to either bulk sediment levels (all contaminants) or levels in the geochemical fractions (metals). In part this is due to the fact that the mechanisms of contaminant uptake by biota in natural systems are not yet fully understood. In addition, the analysis was hampered by the physical characteristics of the study area. The high energy environment that characterizes most flowing water means that sediments deposited in this area are subject to considerable resuspension and deposition of fine-particulate matter due to current action. Therefore, changes in sediment contaminant concentrations can occur both temporally and spatially as a result of purely physical processes. This presents difficulties in relating sediment concentrations with concentrations in organism tissues. The latter would represent concentrations accumulated over the lifetime of the individual, while sediment concentrations would be accumulated over an unknown time period, which may vary from hours to months or years.

Accumulation of organic compounds by benthic organisms was negligible, with most being below detection limits. No accumulation of DDT compounds to any significant levels was observed, despite locally high sediment concentrations. Higher tissue levels of some compounds did occur in isolated cases and suggests that these may be locally more available. In general, bioaccumulation of these compounds seems to be due primarily to availability from the sediments, which in turn is governed by their solubility and fugacity (the tendency of a compound to leave one compartment and move to another). Literature to date indicates that sorption of these compounds is primarily from the dissolved phase and that sediments act principally as either reservoirs for desorption to the water phase (McElroy *et al.* 1989; Smith *et al.* 1988) or as sinks. Knezovich *et al.* (1987) have suggested that the rate of desorption of organic compounds decreases with residence time in the sediments and that desorption may also decrease in fine-grained sediments, perhaps due to the greater number of adsorption sites and the decrease in sediment pore water volume. Desorption from the sediment solid phases would tend to result in increased concentrations in the interstitial water, increasing the potential for biological uptake. The low tissue concentrations in organisms in Canagagigue Creek, despite higher sediment levels, suggests that desorption from the sediment solid phases does not occur readily and suggests that these compounds were more firmly bound to sediment components.

Chlorophenols, though present in the water column were not detected in sediments. However, low concentrations were found in some benthic organisms. The relatively higher solubility of the less chlorinated species would tend to favour higher water column levels and sediment accumulation of these compounds would generally be low. The more highly chlorinated species (e.g. PCP) had they been present would more likely have accumulated in the sediments.

No clear conclusions could be drawn regarding the contribution of sediment contaminants to fish tissue concentrations. The analysis of fish tissues in relation to sediment contamination presents considerable difficulties. Firstly, fish are highly mobile in relation to benthic organisms, and relating tissue residues to sediment concentrations in any one area is problematic. Secondly, bottom feeding fish can accumulate contaminants from two different media. They can acquire contaminants from the water column, through sorption onto external body surfaces, and they can also acquire contaminants through the ingestion of contaminated food items. It is at present difficult to differentiate the body burdens acquired from the sediment from the amount acquired from the water. Therefore, while fish provide an excellent means of assessing they biological availability of contaminants in a waterbody, they are unable to provide much insight into the availability of contaminants from specific sources such as the sediments. The use of sediment in-fauna appears to be a more appropriate means of assessing contaminant availability and uptake from sediment since these organisms are for the most part relatively sessile. Their virtually continuous exposure to sediment contaminants through ingestion of the solid phases as well as through surface adsorption from the interstitial water suggests that the contribution of contaminants from the dissolved phase in the water column would be minimal.

Laboratory bioassays generally indicated that sediments in the study area were not toxic to biota with the exception of the high mortality of fathead minnows in station 0002 sediments. The only potential cause for this high level of mortality that can be determined from the existing data would be the elevated sediment levels of DDT and its metabolites. Further testing should be able to verify these observations. Bioaccumulation during the test period was high for these compounds and suggests

that disturbance of the sediments can make these more available to aquatic organisms, perhaps by increasing the amounts available in solution. Bioaccumulation of other contaminants was generally low but that levels in tissue did increase slightly downstream of the control. These results suggest that most of the metals were tightly bound to the sediments and were unavailable to biota. The slight increase in tissue levels of some of the organic compounds suggests that availability of these to biota is primarily dependent on desorption from the sediments. The data further suggests that during periods of sediment disturbance, such as peak flows, availability could be enhanced.

While laboratory conditions (i.e. mixing, aeration of water) can affect the results of bioassays, bioassays can be used to verify the field observations. Over time sediment bioassays may become a useful surrogate for field collection of data, though this as well depends on the development of mechanistic models for transport and accumulation of contaminants in aquatic systems.

Benthic studies indicate that Canagagigue Creek, at least in the study area, has been heavily impacted by agricultural activity within the watershed. The benthic community both upstream and downstream, was indicative of organically enriched conditions. The dominant fauna in all cases was the species *L. hoffmeisteri*, a typical inhabitant of organic rich sediments. Since *L. hoffmeisteri* is also among the most tolerant to chemical contamination, effects from sediment organic matter and sediment contamination cannot be separated.

The significant reduction in population density of benthic organisms observed downstream at station 0003 can be attributed to discharge from the Elmira STP. However, the effects appear to be due to water column effects rather than sediment effects. Levels of all contaminants at station 0003 were generally lower than at station 0006. While levels of ammonium, sulphate, sodium, and chloride were higher at station 0006, it is possible that incomplete mixing has occurred and that the full effects were not felt on the bottom-dwelling organisms. The effect does appear to be localized to station 0003. Downstream stations, due to higher accumulation of organic matter had significantly larger populations of oligochaetes.

Only generalized conclusions can be derived from studies based on benthic communities. Responses on the community level are the combined effects of both natural environmental factors (i.e., substrate type, depth) and introduced factors (organic and inorganic contaminants, organic matter and physical alterations) and it is extremely difficult to isolate the effects of changes in one phase (e.g. sediment contaminant concentrations) except where such changes have had a pronounced effect.

5. CONCLUSIONS

Based on the results of the study, the following conclusions can be drawn.

1. The Elmira STP is contributing phosphorus, chloride, sulphate, ammonium and nitrite to the river. Bottom water concentrations decreased with diustance downstream, but levels were still above background 3 km downstream.

2. Organic contaminant concentrations in bottom water were below detection limits for most parameters, though increases in concentration of some of the chlorophenols was noted below the Uniroyal site.

3. Sediment concentrations of some metals increased below the STP (copper and chromium) and the Uniroyal site (lead). Sediment metal concentrations were slightly higher where TOC concentrations were also higher.

4. Concentrations of most organic compounds were below detection limits in the sediments with the exception of DDT and its derivatives DDD and DDE. Sediment levels of these were very high in the spring and may be a reflection of material introduced with the spring runoff. Levels were lower in the fall, but still well above the upstream levels, suggesting the bottom is not thoroughly scoured and residual deposits may remain for some time. Sediment levels were highest at the STP site in the spring (6,030 ug/g pp-DDT) and exceeded the Severe Effect Levels of the proposed Provincial Sediment Quality Guidelines immediately below the STP. However, an increase in the levels in sediment was first detected at the Uniroyal site. Levels were highest in sediments at the Uniroyal site in the fall (300 ng/g pp-DDD).

5. Chorophenols were detected in the water column below the Uniroyal site. Chorophenol;s

were not detected in the sediments at any of the stations.

6. Sediment concentrations of a number of PAH compounds were substantially higher below the Uniroyal site, and total PAH exceeded the Lowest Effect Level of the proposed Provincial Sediment Quality Guidelines. Sediment concentrations decreased downstream.

7. Benthic organism tissue residues of arsenic, copper, cadmium, mercury and zinc exceeded sediment concentrations at one or more stations. Zinc, cadmium and mercury tissue residues were higher than sediment concentrations below either the STP or the Uniroyal site. Copper and arsenic tissue residues were higher than sediment concentrations at all stations.

8. Organic compounds did not bioaccumulate to any significant degree in benthic organisms. Concentrations of DDT and related compounds, though very high in sediments, were low in benthic organisms.

9. No significant increases in tissue metal concentrations could be detected in bottom-feeding fish collected in this study. Accumulation of pp-DDE did occur in one species downstream of the STP.

10. Laboratory sediment bioassay results on fathead minnows suggested the presence of a toxic effect in the sediments from the Uniroyal site. A likely candidate may be an organic contaminant such as one of the DDT group of compounds. This warrants further investigation.

11. Bioaccumulation of a number of contaminants occurred in both fathead minnows and mayflies during laboratory tests on sediments from areas downstream of the control. Disturbance of the sediments appears to increase the availability of some of the contaminants.

12. Effects of sediment contamination on the species composition and density of the benthic community could not be differentiated from other effects. A suppression of both organism density and diversity were noted below the STP outfall, and these can be attributed to a combination of sediment type and the concentrations of contaminants in the water. The benthic community in general appears to be strongly influenced by the presence of organic matter, (likely a result of agricultural activity within the drainage basin), which obscures any potential effects from contaminants.

6. RECOMMENDATIONS

The high levels of DDT and its metabolites DDD and DDE raises some concerns and efforts should be made to properly identify the sources. Selected stations should be revisited periodically to determine whether the sources are being cleaned up.

The most useful remedial action would be an effective control of contaminant sources. While sediment concentrations of DDT are high, these do not appear to be available for uptake by organisms, and thus do not pose an immediate threat to organisms. Therefore, removal and disposal of sediment should be carefully evaluated to ensure that this does not pose more of a threat to aquatic organisms than leaving the sediments in place.

7. REFERENCES

ANDREWS, D. 1988. Availability of Zinc to Benthic Organisms from Sediment Fractions. Report for the Ont. Ministry of the Environment. RAC Proj. 277RR.

BECKETT, D.C. & J.L. KEYES. 1983. A Biological Appraisal of Water Quality in the Ohio River Using Macroinvertebrate Communities, With Special Emphasis On the Chironomidae. pp 15-33. In:Roback, S.S. (ed.), Proc. 8th Internat. Symp. on Chironomidae. Mem. Amer. Ent. Soc. No. 34.

BRINKHURST, R.O. and C.R. KENNEDY. 1965. Studies on the Biology of the Tubificidae (Annelida, Oligochaeta) in a Polluted Stream. J. Anim. Ecol. 34: 429-443.

BUSCEMI, P.A. 1966. The Importance of Sedimentary Organics in the Distribution of Benthic Organisms. pp 79-86. In: K.W. Cummins [ed.] Organism - Substrate Relationships. Pymatuning Lab. of Ecology, Spec. Publ. No. 4.

CALMANO, W., W. AHLF and U. FORSTNER. 1988. Study of Metal Sorption/Desorption Processes on Competing Sediment Components with a Multichamber Device. Environ. Geol. Water Sci. 11: 77-84.

CAREY, J.H., M.E. FOX, B.G. BROWNLEE, J.L. METCALFE, P.D. MASON and W.H. YEREX. 1983. The Fate and Effects of Contaminants in Canagagigue Creek. 1: Stream Ecology and Identification of Major Contaminants. Environ. Canada Sci. Ser. No. 135.

CHAPMAN, P.M., M.A. FARRELL, and R.O. BRINKHURST. 1982a. Relative Tolerance of Selected Aquatic Oligochaetes to Individual Pollutants and Environmental Factors. Aquat. Toxicol. 2: 47-67.

CHAPMAN, P.M., M.A. FARRELL, and R.O. BRINKHURST. 1982b. Relative Tolerances of Selected Aquatic Oligochaetes to Combinations of Pollutants and Environmental Factors. Aquat. Toxicol. 2: 69-78.

EVANS, R.D., D. ANDREWS, and R.J. CORNETT. 1988. Chemical fractionation and bioavailability of cobalt-60 to benthic deposit feeders. Can. J. Fish. Aquat. Sci. 45: 228-236.

JAAGUMAGI, R. 1988. The In-Place Pollutants Program. Vol V, Part B - Benthic Invertebrate Studies - Results. Rept. to Ont. Ministry of the Environment. 74 pp.

JOHNSON, M.G., O.C. MCNEIL & S.E. GEORGE. 1987. Benthic Macroinvertebrate Associations in Relation to Environmental Factors in Georgian Bay. J. Great Lakes Res. 13(3): 310-327.

KENNEDY, C.R. 1965. The Distribution and Habitat of *Limnodrilus* Claparede (Oligochaeta: Tubificidae). Oikos 16: 26-38.

KNEZOVICH, J.P., F.L. HARRISON and R.G WILHELM. 1987. The Bioavailability of Sediment-sorbed Organic Chemical: A Review. Wat. Air Soil Pollut. 32: 233-245.

KNOWLTON, M.F., T.P. BOYLE and J.R. JONES. 1983. Uptake of Lead from Aquatic Sediment by Submersed Macrophytes and Crayfish. Arch. Environ. Contam. Toxicol. 12: 535-541.

LANDAHL, C-C,. & B. NAGELL. 1978. Influence of the Season and of Preservation Methods on Wet and Dry Weight of the Larvae of *Chironomus plumosus* L. Int. Revue ges Hydrobiol. 63: 405-410.

LUOMA, S.N. 1983. Bioavailability of Trace Metals to Aquatic Organisms - A Review. Sci. Tot. Environ. 28: 1-22.

McELROY, A.E., J.W. FARRINGTON and J.M. TEAL. 1989. Chapter 1: Bioavailability of PAH in the Aquatic Environment. pgs. 1-40. In: U. Varanasi [ed]. Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment. CRC Press, Boca Raton, FL.

OLIVER, B.G and M.N. CHARLTON. 1984. Chlorinated Organic Contaminants on Settling Particles in the Niagara River Vicinity of Lake Ontario. Environ. Sci. Technol. 18: 903-908.

OCEANCHEM, 1988. OMOE In-Place Pollutants Program: Analysis of Aquatic Biota. Rept. to the Ont. Ministry of the Environment.

ONTARIO MINISTRY OF THE ENVIRONMENT 1983. Handbook of Analytical Methods for Environmental Samples. Vol I and II. OMOE, Toronto.

ONTARIO MINISTRY OF THE ENVIRONMENT 1989. The Development Document for the Effluent Monitoring Regulation for the Organic Chemical Manufacturing Sector. OMOE, Toronto.

PERSAUD, D, R. JAAGUMAGI & A. HAYTON. 1990. Provincial Sediment Quality Guidelines. OMOE, Toronto. 21 pp.

PERSAUD, D., T.D. LOMAS, and A. HAYTON. 1987. The In-Place Pollutants Program. Vol. III, Phase 1 Studies. Ont. Ministry of the Environment. 94 pp.

PERSAUD, D. and W.D. WILKINS. 1976. Evaluating Construction Activities

Impacting Water Resources. Ont. Ministry of the Environment.

SMITH, J.A., P.J. WITKOWSKI, and T.V. FUSILLO. 1988. Manmade Organic Compounds in the Surface Waters of the United States - A Review of Current Understanding. U.S. Geol. Surv. Circ. 1007. 92 pp.

SMOCK, L.A. 1983. Influence of Feeding Habits on Whole-Body Metal Concentrations in Aquatic Insects. Freshwat. Biol. 13: 301-311.

STUMM, W. and J.J. MORGAN. 1981. Aquatic Chemistry. Second Edition. Wiley-Interscience. Toronto. 780 pp.

TESSIER, A. 1979. Sequential Extraction Procedure for the Speciation of Particulate Trace Metals. Anal. Chem. 51:844-851.

WAKEHAM, S.G., C. SCHAFFNER and W. GIGER. 1980. Polycyclic Aromatic Hydrocarbons in Recent Lake Sediments - 1. Compounds Having Anthropogenic Origins. Geochim Cosmochim Acta 44: 403-413.

WINNER, R.W., M.W. BOESEL, and M.P. FARRELL. 1980. Insect Community Structure as an Index of Heavy-metal Pollution in Lotic Ecosystems. Can. J. Fish. Aquat. Sci. 37: 647-655.

WIEDERHOLM, T. & L. ERIKSSON. 1977. Effects of Alcohol Preservation on the Weight of Some Benthic Invertebrates. Zoon 5 (1): 29-32.

Appendix 1

8. Figures

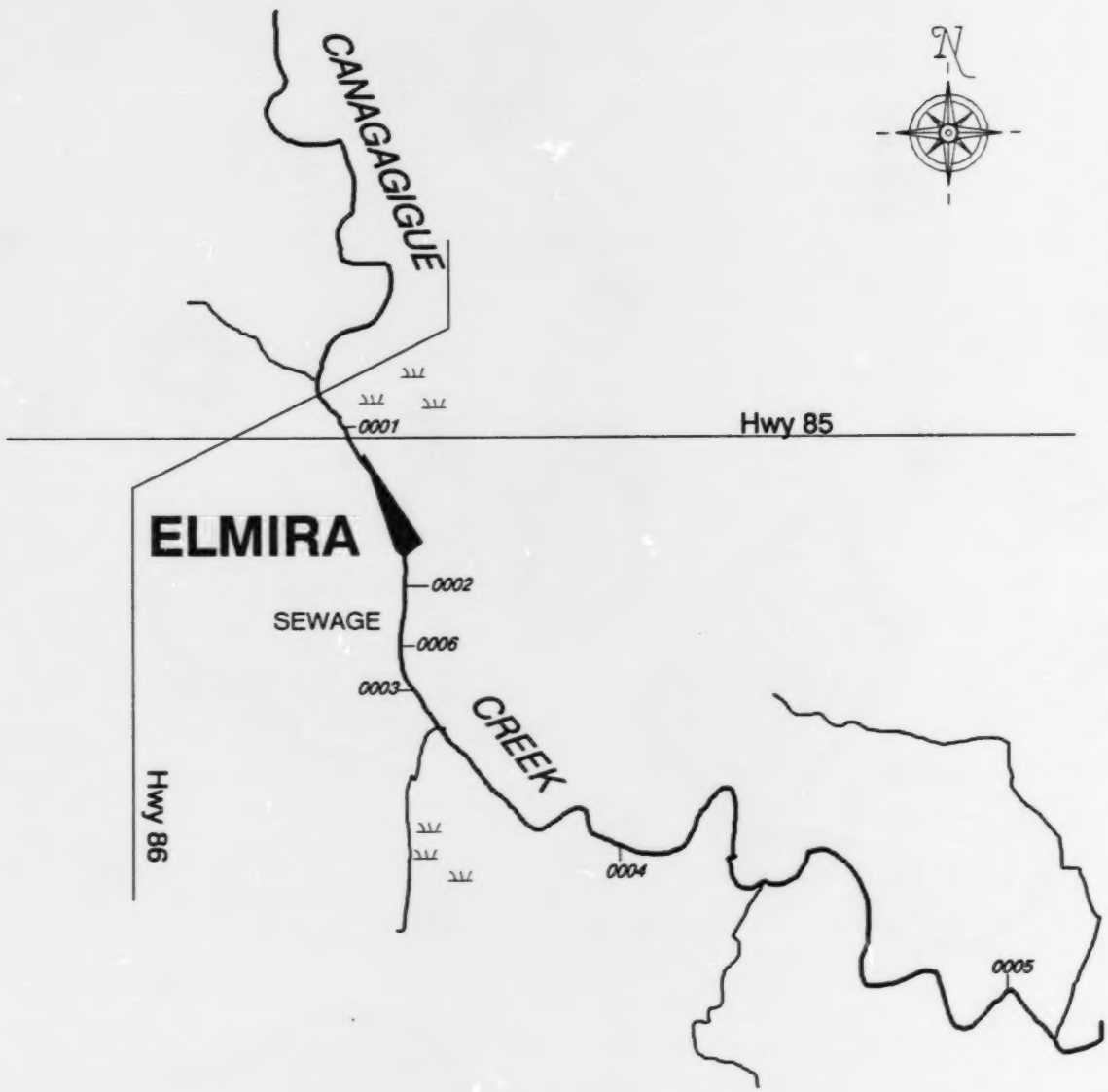


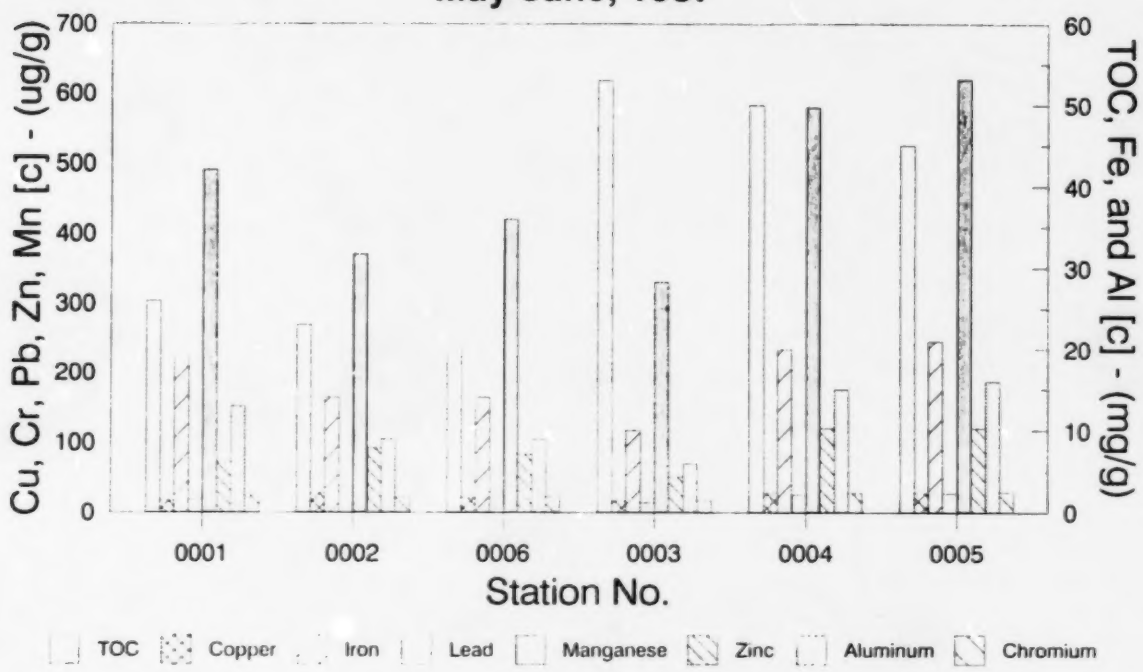
Fig 1. Canagagigue Creek

Location of Sampling Sites
May, 1987

1 Km

Ontario
Ministry of the Environment

Fig. 2a. Sediment Metal and TOC Concentrations
Canagagigue Creek
May-June, 1987



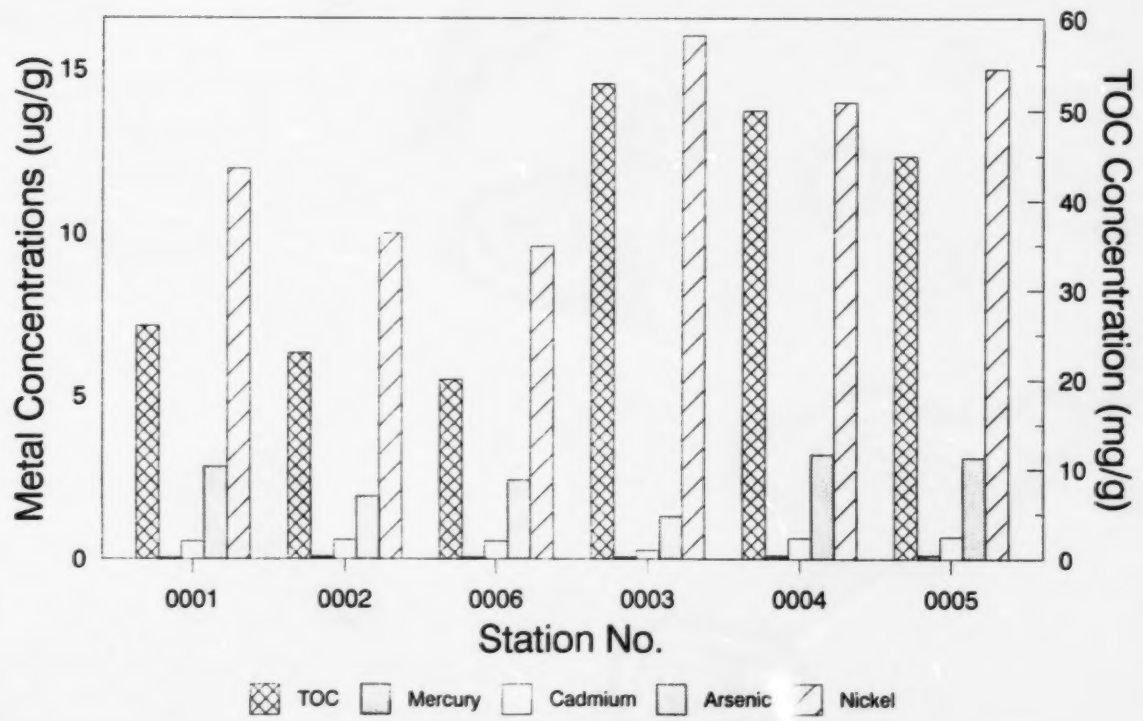
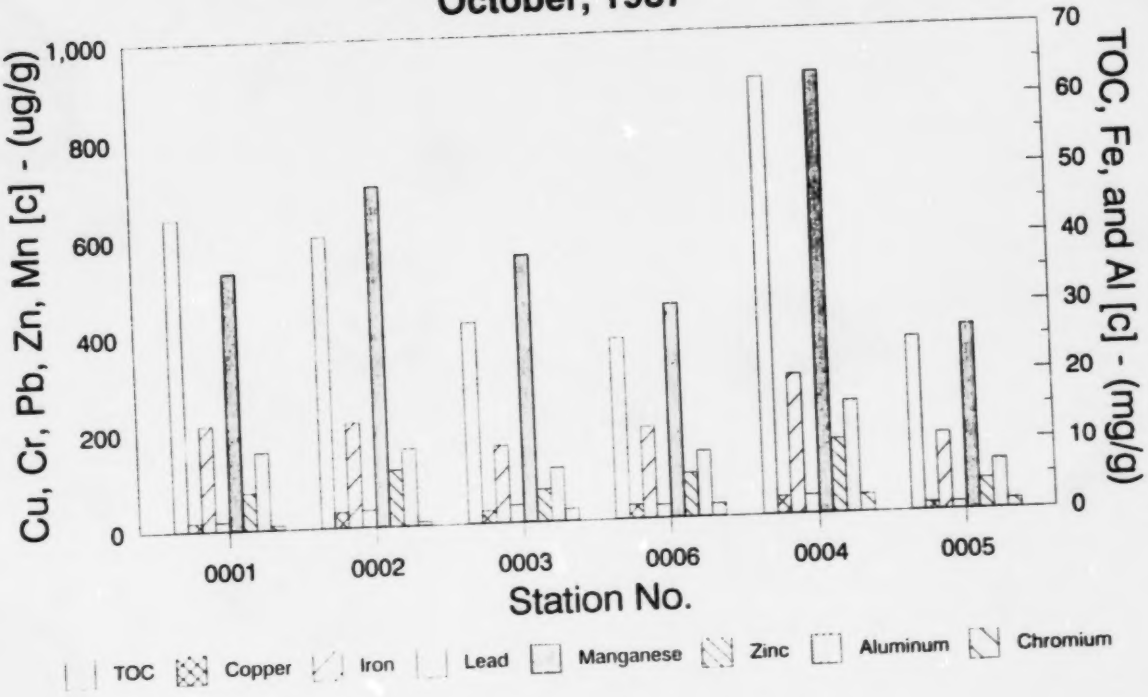


Fig. 2b: Sediment Metal and TOC Concentrations
Canagagigue Creek
October, 1987



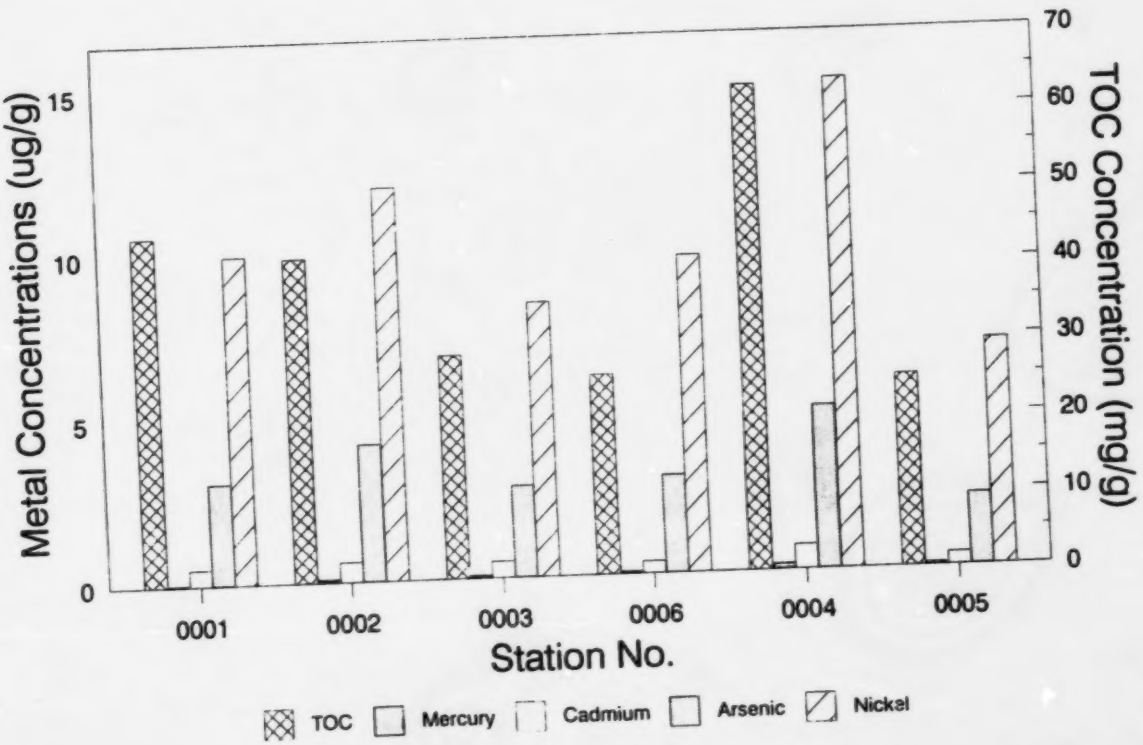


Fig.3a: Distribution of PAHs in Canagagigue Creek Sediments

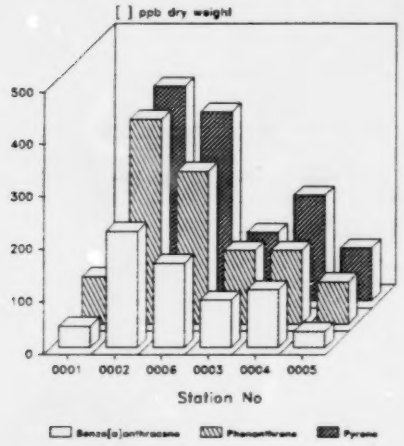


Fig.3b: Distribution of PAHs in Canagagigue Creek Sediments

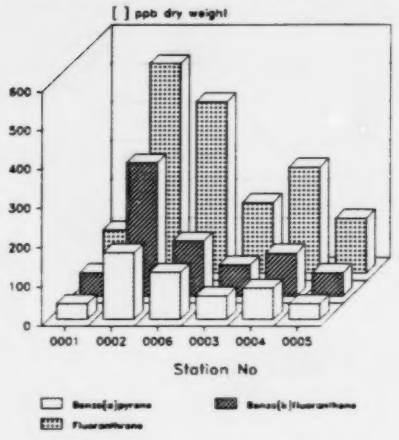
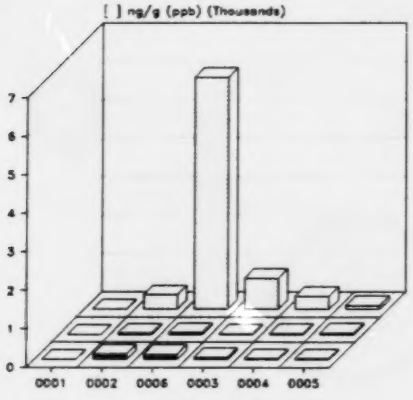


Fig.4: Sediment Distribution of pp-DDT and Metabolites



(Data from May-June Survey, 1987)

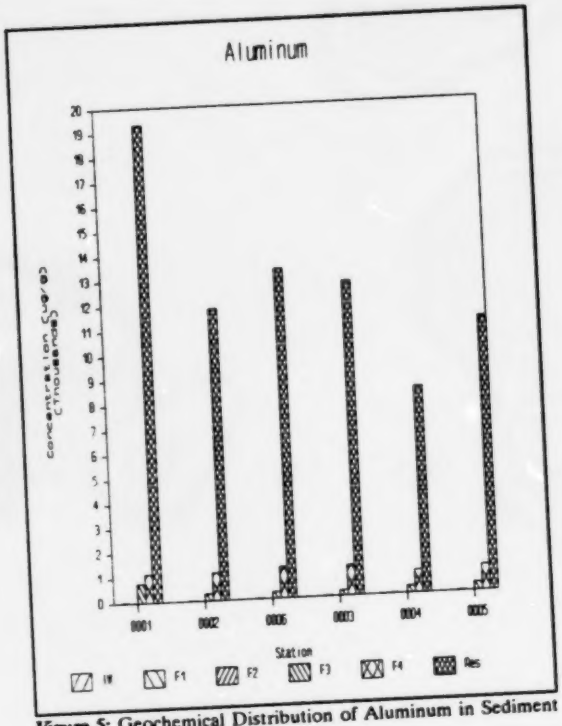


Figure 5: Geochemical Distribution of Aluminum in Sediment (wet weight)

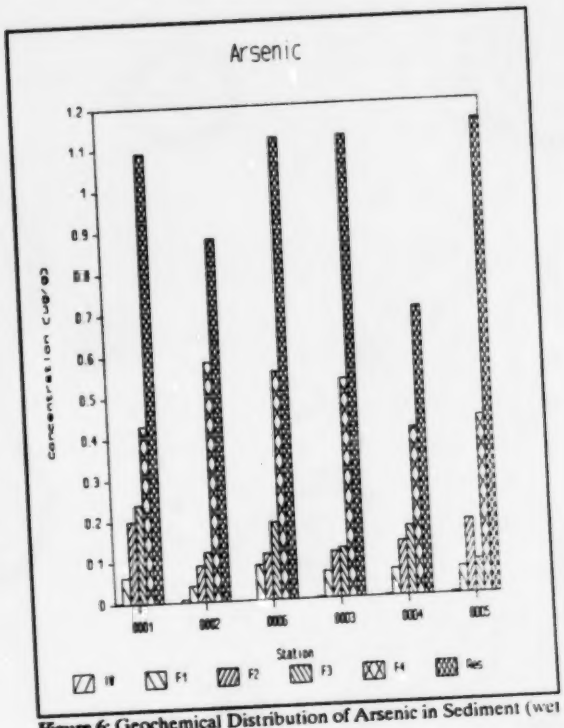


Figure 6: Geochemical Distribution of Arsenic in Sediment (wet weight)

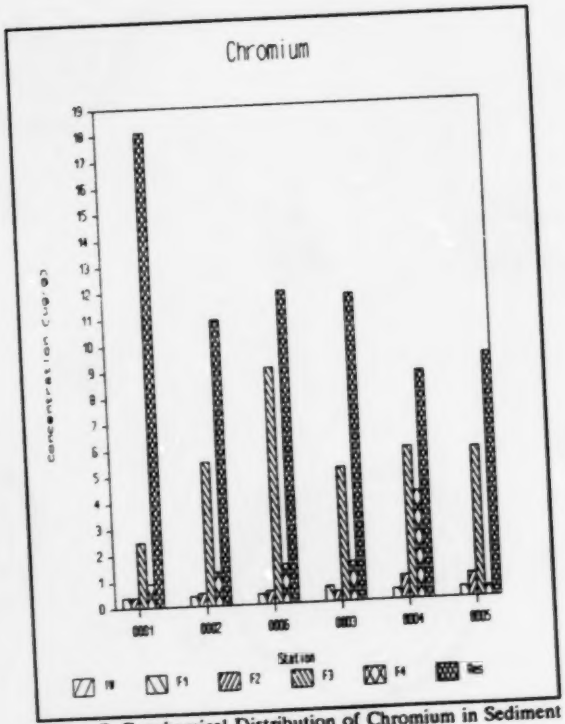


Figure 7: Geochemical Distribution of Chromium in Sediment (wet weight)

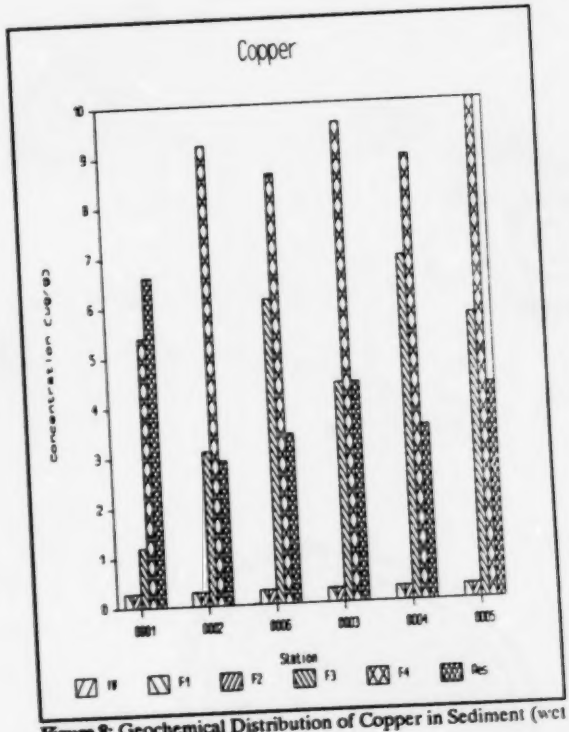


Figure 8: Geochemical Distribution of Copper in Sediment (wet weight)

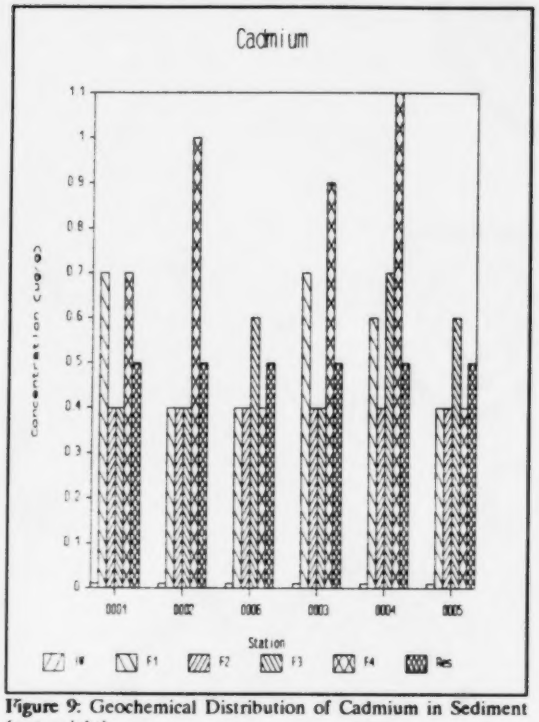


Figure 9: Geochemical Distribution of Cadmium in Sediment (wet weight)

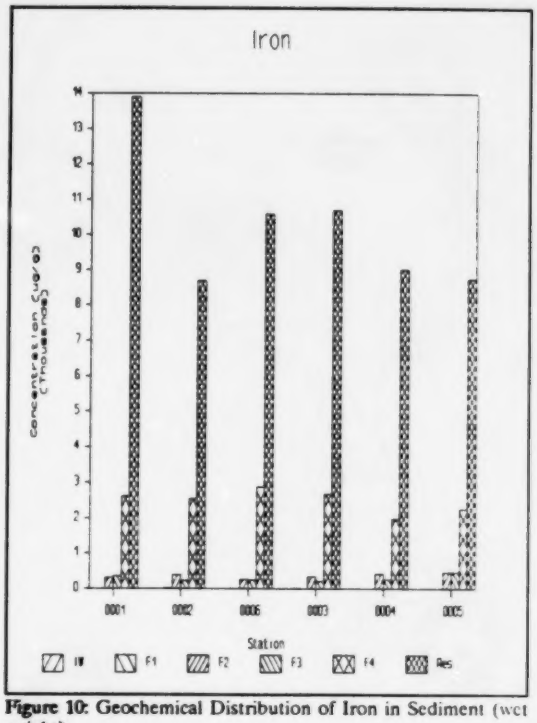


Figure 10: Geochemical Distribution of Iron in Sediment (wet weight)

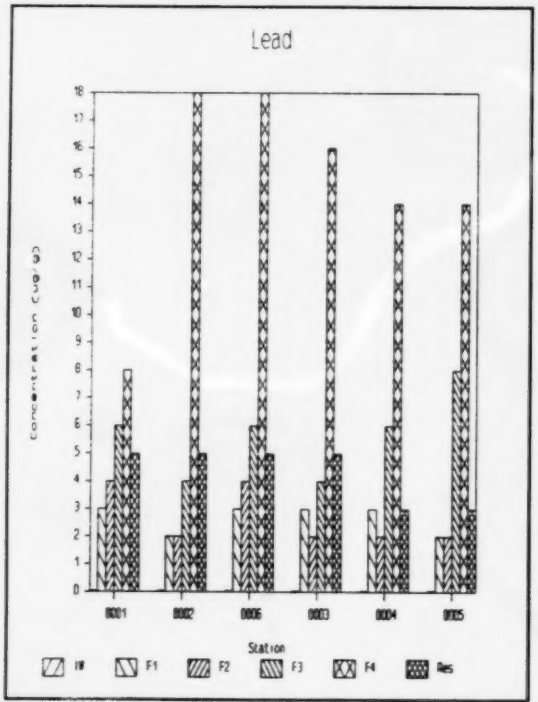


Figure 11: Geochemical Distribution of Lead in Sediment (wet weight)

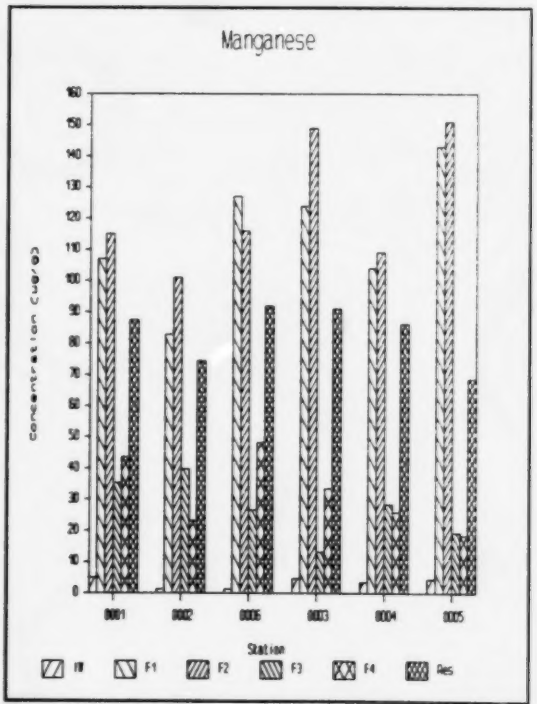


Figure 12: Geochemical Distribution of Manganese in Sediment (wet weight)

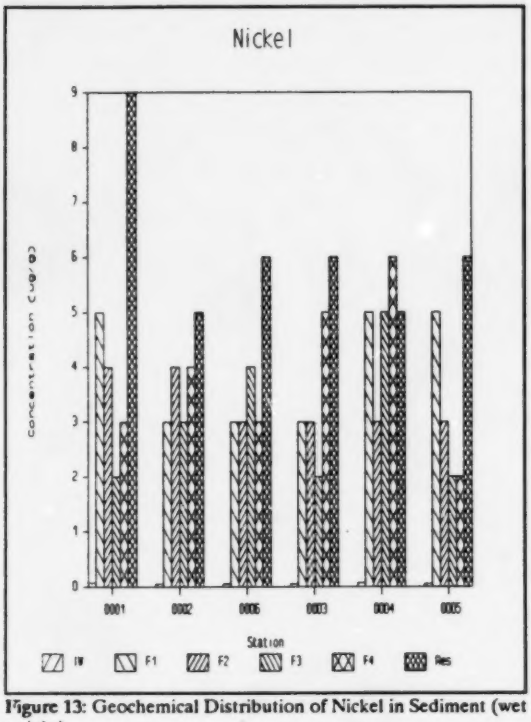


Figure 13: Geochemical Distribution of Nickel in Sediment (wet weight)

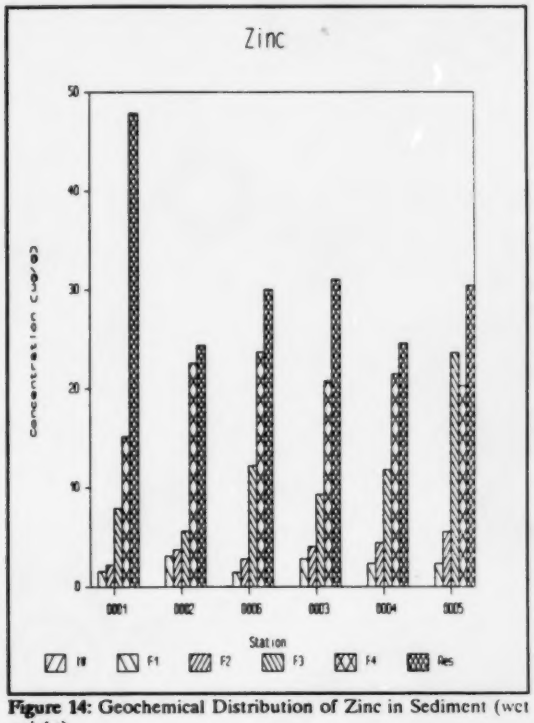
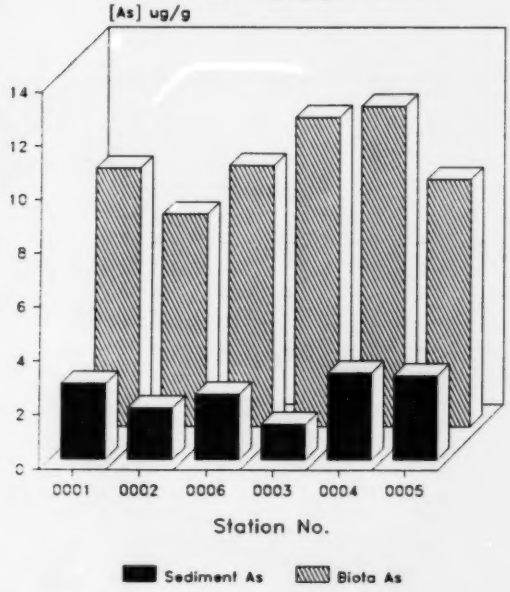


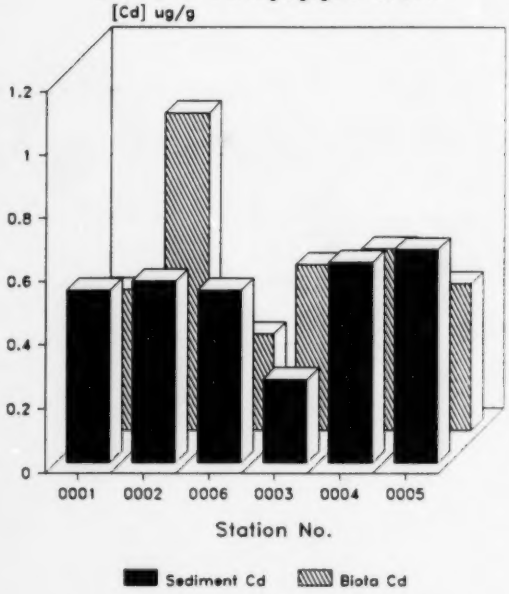
Figure 14: Geochemical Distribution of Zinc in Sediment (wet weight)

Fig.15a: Sediment–Invertebrate Arsenic Levels – Canagagigue Creek



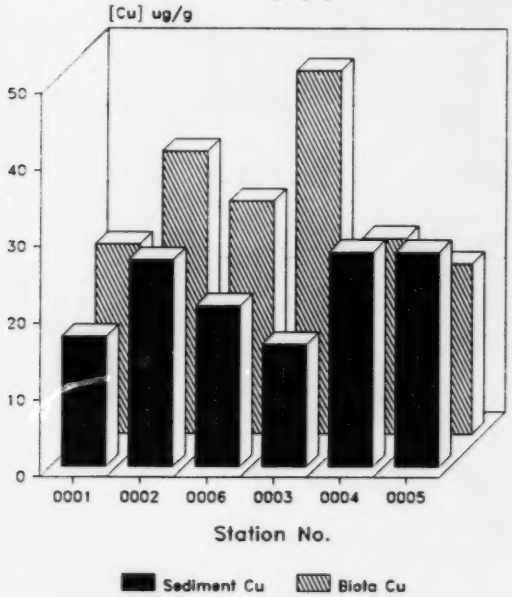
Biota levels are gut corrected dry weight

Fig.15b: Sediment–Invertebrate Cadmium Levels – Canagagigue Creek



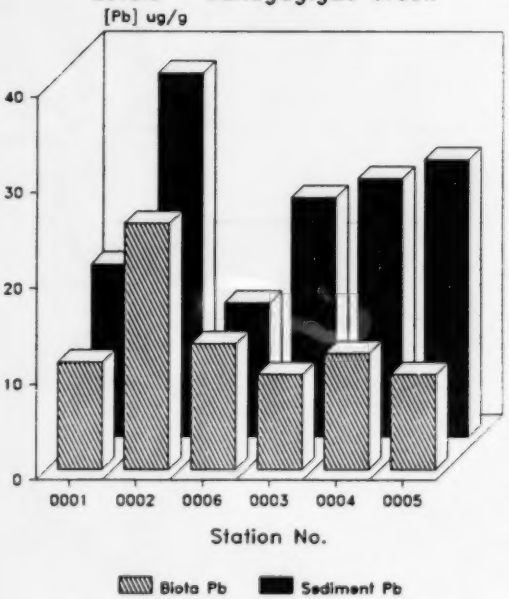
Biota levels are gut corrected dry weight

Fig.15c: Sediment–Invertebrate Copper Levels – Canagagigue Creek



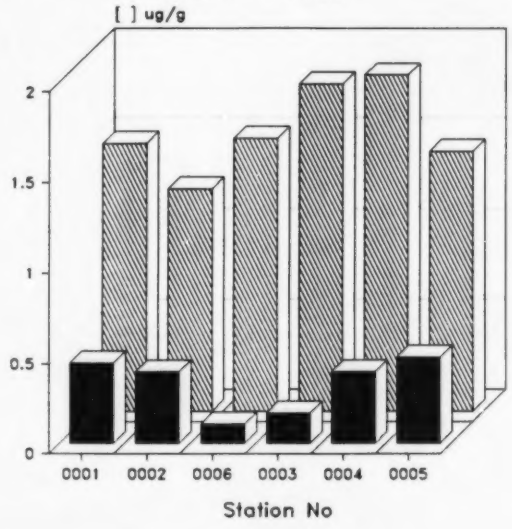
Biota levels are gut corrected dry weight

Fig.15d: Sediment–Invertebrate Lead Levels – Canagagigue Creek



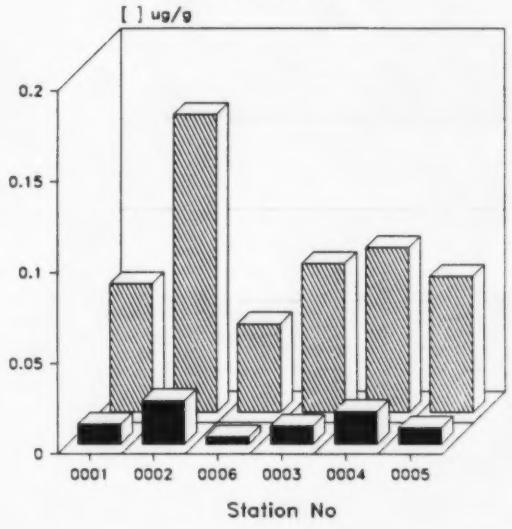
Biota levels are gut corrected dry weight

Fig. 16a: Fish–Invertebrate Arsenic Levels in Tissue



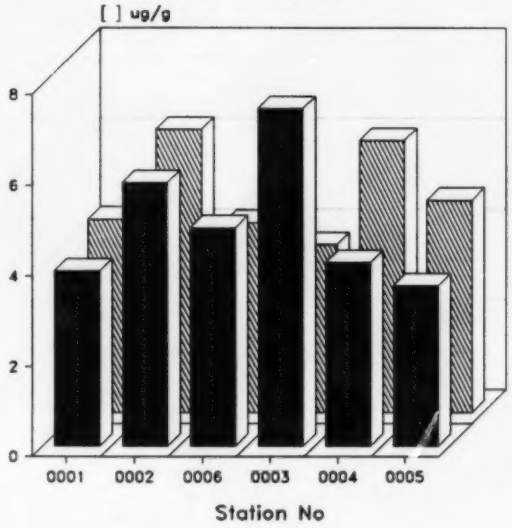
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16b: Fish–Invertebrate Cadmium Levels in Tissue



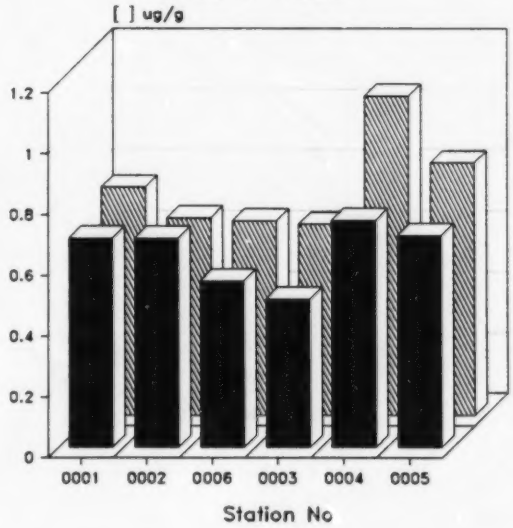
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16c: Fish–Invertebrate Copper Levels in Tissue



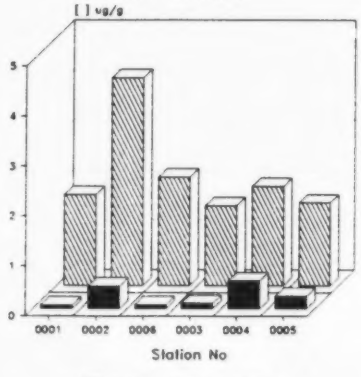
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16d: Fish–Invertebrate Chromium Levels in Tissue



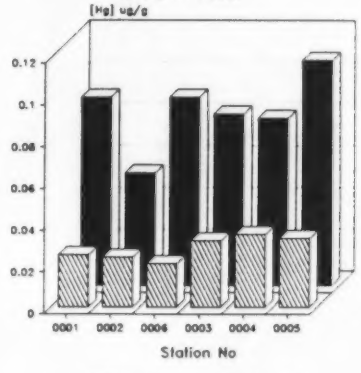
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16e: Fish–Invertebrate Lead Levels in Tissue



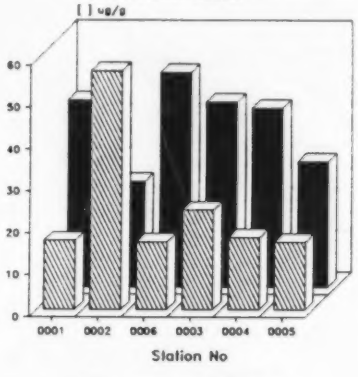
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16f: Fish–Invertebrate Mercury Levels in Tissue



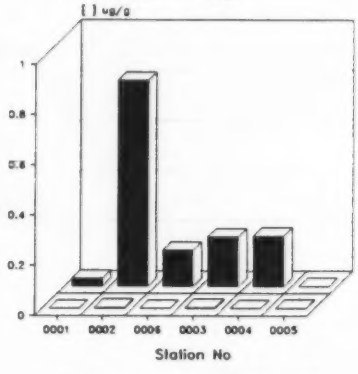
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16g: Fish–Invertebrate Zinc Levels in Tissue



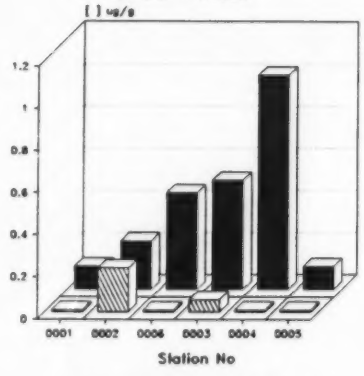
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16h: Fish–Invertebrate pp–DDE Levels in Tissue



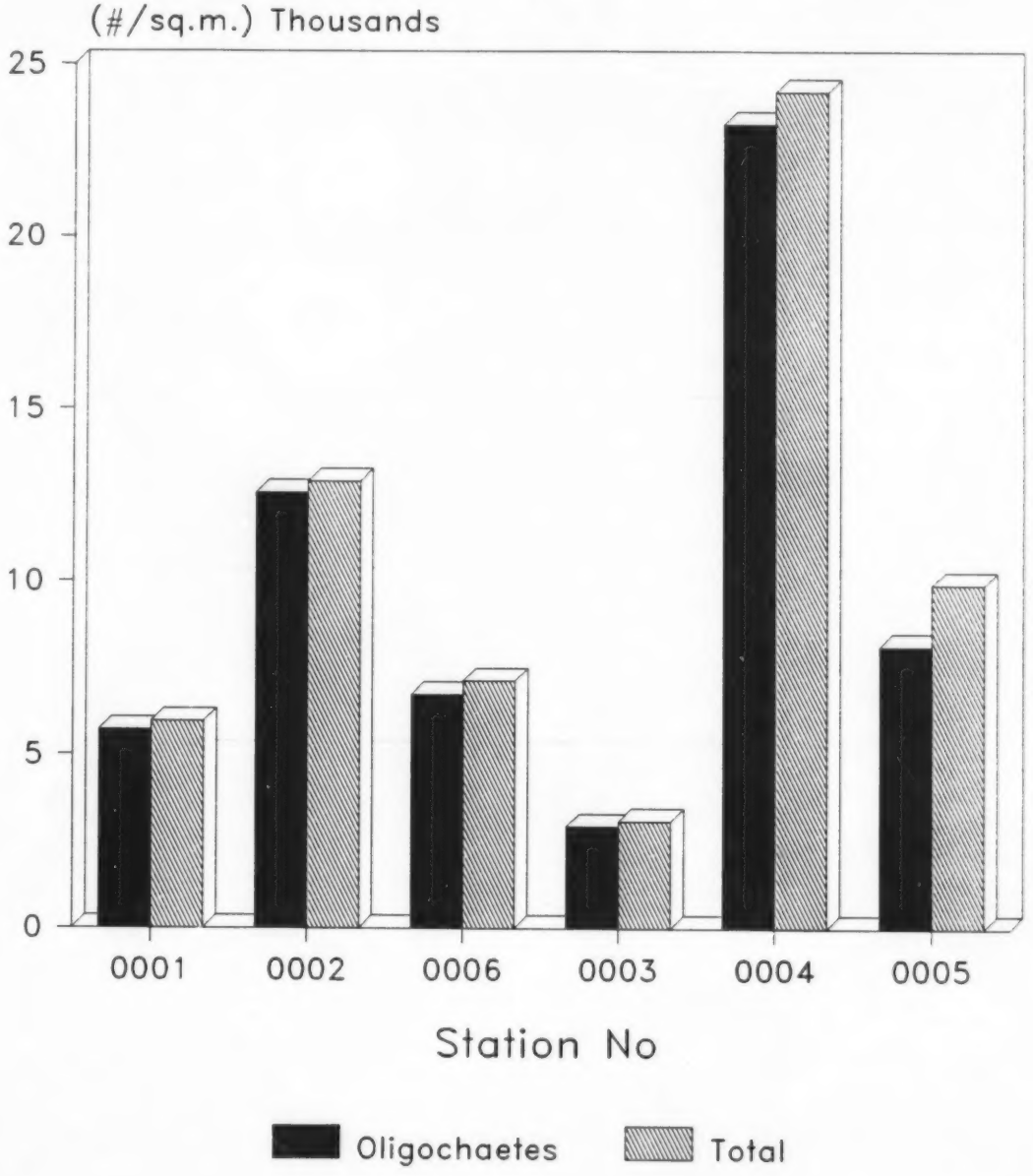
Tissue levels are wet weight
and not corrected for gut contents

Fig. 16i: Fish–Invertebrate PCB Levels in Tissue



Tissue levels are wet weight
and not corrected for gut contents

Fig. 17: Distribution of Oligochaetes in Relation to the Total Fauna



Appendix 2

9. Tables

TABLE 1: In-Place Pollutants Program
1987 Canagagigue Creek Study
Water - Nutrients, pH, IONS
(MAY-JUNE)

Location	Station	Depth	Conductivity @ 25 c	Hardness	Sodium	Potassium	Alkalinit	pH	Acidity Total	Fluoride	Chloride	Sulphate	Residue Filtrate	Residue Particulate
		m	umho/cm	mg/L	mg/L	mg/L	mg/L	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CANAGAGIGUE CREEK	0001	0.1-0.2	516.0	250.0	9.8	3.40	207.5	7.95	-	0.10	18.6	33.2	318.0	29.7
	0002	0.1-0.2	643.0	289.0	21.3	3.47	218.0	8.03	-	0.13	35.5	70.1	408.0	24.1
	0006	0.1-0.2	1700.0	313.0	239.0	4.81	215.8	8.02	-	0.16	157.0	416.0	-	-
	0003	0.1-0.2	1650.0	318.0	229.0	4.69	215.7	7.90	0.59	0.16	152.0	356.0	1090.0	28.3
	0004	0.2	1490.0	317.0	198.0	4.51	215.5	8.01	-	0.16	140.0	299.0	976.0	23.7
	0005	0.2	813.0	329.0	43.6	3.56	215.3	8.32	-	0.19	57.0	141.0	536.0	3.3

KEY: - NO DATA
CR CALCULATED RESULT

Location	Station	Turbidity	Colour True	Phosphorus	Nitr'n Total	Ammonium Total Frac. Reac.	Nitrates Total Frac. Reac.	Nitrite Frac. Reac	Phenolics	Chemical Oxygen Demand	Dissolved Organic Carbon	Dissolved Inorganic Carbon
		TURB	COL TRE	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L
CANAGAGIGUE CREEK	0001	16.4	13.5	0.156	0.79 <T	0.006	3.87	0.0100	-	16.0	4.4	43.0
	0002	19.7	14.0	0.150	1.11	0.414	3.26	0.1680	-	16.6	4.3	46.0
	0006	21.0	12.5	0.215	1.03	0.324 >	4.66 >	0.2340	-	17.6	3.7	44.0
	0003	21.0	14.0	0.230	1.02	0.352 >	4.66 >	0.2350	-	19.7	3.8	44.0
	0004	10.6	15.5	0.205	0.76	0.076 >	4.65 >	0.2340	-	16.6	3.9	44.0
	0005	2.7	13.0	0.210	0.65 <T	0.008	3.24 >	0.2340	-	15.3	4.4	45.0

KEY: <T THIS LOW MEASUREMENT IS TENTATIVE - FOR INFORMATION ONLY
- NO DATA
> RESULT GREATER THAN REPORTED VALUE

TABLE 2: In-Place Pollutants Program

1986 Canagagigue Creek Study

Water - Metals

(MAY-JUNE)

Location	Station	Depth	Field Ph	Field EH	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel	Calcium
	#				mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CANAGAGIGUE RIVER	0001	0.1-0.2	7.84	-	0.002	0.001	<0.01	<0.0003	0.900	<0.003	0.002	<0.001	0.130	0.640	<0.002	73.000
	0002	0.1-0.2	8.00	-	-	-	<0.01	-	-	-	-	<0.001	-	-	-	-
	0006	0.1-0.2	8.02	-	-	-	0.01	-	-	-	-	<0.001	-	-	-	-
	0003	0.1-0.2	8.02	-	-	-	0.01	-	-	-	-	<0.001	-	-	-	-
	0004	0.2	8.07	-	-	-	0.01	-	-	-	-	<0.001	-	-	-	-
	0005	0.2	8.41	-	-	-	<0.01	-	-	-	-	<0.001	-	-	-	-

KEY: < LOWER THAN DETECTION LIMIT

- NO DATA

ABLE 3: In-Place Pollutants Program
1987 Canagagigue Study
Water - PCB & Pesticides
Units: ng/L
(MAY-JUNE)

ocation	Station	Depth	Aldrin	A-BHC Hexa-chloro cyclo hexane	B-BHC Hexa-chloro cyclo hexane	G-BHC Hexa-chloro cyclo hexane	A chlor-dane	G chlor-dane	Dieldrin	DMDT meth-oxychlor	Endo-sulfan I	Octa Chloro-Styrene	Endo-sulfan II	Endrin	Endo-sulfan sulfate	Hepta-chlor-epoxide	Hepta-chlor	Mirex	Oxy-chloro-dane	OP-DDT	PCB Total	PP-DDD	PP-DDE	PP-DDT	Hexa-chloro-benzene
NAGAGIGUE CREEK	0001	0.1-0.2	<1	<T 2	<T 2	<T 3	<2	<2	<2	<5	<2	<1	<4	<4	<4	<1	<1	<5	<2	<5	<20	<5	<1	< 5	<1
	0002	0.1-0.2	<1	< 1	< 1	14	<2	<2	<2	<5	<2	<1	<4	<4	<4	<1	<1	<5	<2	<5	<20	<5	<1	< 5	<1
	0006	0.1-0.2	<1	< 1	< 1	45	<2	<2	<2	<5	<2	<1	<4	<4	<4	<1	<1	<5	<2	<5	<20	<5	<1	<T 17	<1
	0003	0.1-0.2	<1	<T 1	< 1	44	<2	<2	<2	<5	<2	<1	<4	<4	<4	<1	<1	<5	<2	<5	<20	<5	<1	< 5	<1
	0004	0.2	<1	< 1	< 1	30	<2	<2	<2	<5	<2	<1	<4	<4	<4	<1	<1	<5	<2	<5	<20	<5	<1	< 5	<1
	0005	0.2	<1	< 1	< 1	15	<2	<2	<2	<5	<2	<1	<4	<4	<4	<1	<1	<5	<2	<5	<20	<5	<1	< 5	<1

< LOWER THAN DETECTION LIMIT
<T THIS LOW MEASUREMENT IS TENTATIVE - FOR INFORMATION ONLY
- NO DATA

ABLE 4: In-Place Pollutants Program
1987 Canagagigue Creek Study
Water - Organics
Units: ng/L
(MAY-JUNE)

ocation	Station	Depth	Hexa-chloro ethane	1,3,5 Trichloro benzene	1,2,4 Trichloro benzene	Hexa Chloro-butadiene	1,2,3 Trichloro benzene	2,4,5 Trichloro toluene	2,3,6 Trichloro toluene	1,2,3,5 Tetrachloro benzene	1,2,4,5 Tetrachloro benzene	2,6,a Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene	Toxa-Phene	Dicamba
NAGAGIGUE CREEK	0001	0.1-0.2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	< 50
	0002	0.1-0.2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	< 50
	0006	0.1-0.2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	< 50
	0003	0.1-0.2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	< 50
	0004	0.2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	< 50
	0005	0.2	<1	<5	< 5	<1	<50	<5	<5	<1	<1	<5	<1	<1	-	< 50

Y: < LOWER THAN DETECTION LIMIT
<T THIS LOW MEASUREMENT IS TENTATIVE - FOR INFORMATION ONLY
- NO DATA

ABLE 5: In-Place Pollutants Program
1987 Canagagigue Creek Study
Water - Chlorophenols
Units: ng/g
(MAY-JUNE)

ocation	Station	Depth	Trichorophenols 234	245	246	Tetrachlorophenols 2345	2356	Pentachloro-phenols
		m						
NAGAGIGUE CREEK	0001	0.1-0.2	<100	< 100	< 20	<20	<10	< 10
	0002	0.1-0.2	<100	<T120	<T100	<20	<10	< 10
	0006	0.1-0.2	<100	< 100	<T 80	<20	<10	< 10
	0003	0.1-0.2	<100	< 100	< 20	<20	<10	< 10
	0004	0.2	<100	< 100	<T100	<20	<10	< 10
	0005	0.2	<100	< 100	< 20	<20	<10	< 10

Y: < LOWER THAN DETECTION LIMIT
<T THIS LOW MEASUREMENT IS TENTATIVE - FOR INFORMATION ONLY

TABLE 6: In-Place Pollutants Program

1986 Canagagigue Creek Study

Sediment - Particle Size by percentage

Units: um

(MAY-JUNE)

Location	Station	Gravel >1000	Sand 1000-44	Silt 42.21-3.73	Clay 3.73-0.17
CANAGAGIGUE CREEK	0001	0.1	32.0	49.8	15.8
	0002	3.2	44.9	37.4	11.9
	0006	0.1	53.6	34.0	10.9
	0003	0.8	67.2	23.3	6.8
	0004	0.7	21.8	59.0	15.8
	0005	0.4	22.8	58.4	16.3

(OCTOBER)

Location	Station	Gravel >1000	Sand 1000-44	Silt 42.21-3.73	Clay 3.73-0.17
CANAGAGIGUE CREEK	0001	0.4	62.40	28.80	5.80
	0002	0.3	55.70	19.20	3.10
	0003	1.4	60.50	29.80	5.10

KEY: - NO DATA

Table 7: In-Place Pollutants Program
1987 Canagagigue Creek Study
Sediment - Metals
Units: Dry weight
(MAY - JUNE)

Location	Station	Field Ph	Field EH	Loss on Ignition	Phosphorous	Total Kjeldahl Nitrogen	Total Organic Carbon	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel	Solvent Extractables
				%	mg/g	mg/g	mg/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
CANAGAGIGUE CREEK	0001	7.51	-160	5.9 *	1.20 *	2.0 *	26.0	17.0	24.0	0.03	0.54 *	19000	18.0	72.0	2.80	490.0	13000	12.0	1250
	0002	7.45	-185	5.6 *	1.00 *	2.2 *	23.0 *	27.0	22.0	0.08	0.57 *	14000	38.0	92.0	1.90	370.0	9000	10.0 *	3400
	0006	6.66	-230	4.8 *	1.10 *	2.0 *	20.0	21.0	22.0	0.05	0.54 *	14000	29.0	83.0	2.40	420.0	9000	9.6 *	2640
	0003	7.15	-230	3.5 *	2.80	1.2 *	53.0	16.0	17.0	0.05	0.26 *	10000	14.0	51.0	1.30	330.0	6000	16.0	1170
	0004	7.11	-210	7.5 *	1.90 *	3.6 *	50.0 *	28.0 *	28.0	0.11	0.63 *	20000	25.0 *	120.0	3.20	580.0	15000	14.0 *	2510
	0005	7.35	-215	6.0 *	1.90 *	3.5 *	45.0 *	28.0 *	29.0	0.12	0.67 *	21000	27.0 *	120.0	3.10	620.0	16000	15.0 *	3050

KEY: - NO DATA
* EQUALS OR EXCEEDS MOE GUIDELINES FOR OPEN WATER DISPOSAL OF DREDGED MATERIAL
AV RESULT IF THE AVERAGE OF <2 ANALYSES

(OCTOBER)

Station	Field Ph	Field EH	Loss on Ignition	Phosphorous	Total Kjeldahl Nitrogen	Total Organic Carbon	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel	Solvent Extractables
			%	mg/g	mg/g	mg/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	Sol. Ext. ug/g
0001	-	-	6.2 *	1.02 *	1.70	45.0 *	17.0	9.0	0.04	0.50	*15000	18.0	75.0	3.10	530.0	11000	10.0	9825
0002	-	-	7.4 *	1.18 *	2.42 *	42.0 *	32.0 *	8.0	0.09	0.60	*15000	34.0	*11	4.20	700.0	11000	12.0	14266
0006	-	-	3.6	0.75	1.09	26.0 *	28.0 *	24.0	0.06	0.36	*11000	35.0	65.0	2.80	550.0	7600	8.4	831
0003	-	-	5.3	1.17 *	2.21 *	29.0 *	25.0 *	25.0 *	0.08	0.50	*13000	26.0	89.0	3.00	440.0	9300	9.7	803
0004	-	-	8.5 *	1.77 *	2.36 *	63.0 *	35.0 *	35.0 *	0.16	0.73	*20000	37.0	*15	5.00	910.0	16000	15.0	1200
0005	-	-	4.6	1.13 *	1.42	25.0 *	15.0	19.0	0.07	0.37	*11000	15.0	61.0	2.20	380.0	7000	6.9	2596

KEY - NO DATA
* EQUALS OR EXCEEDS MOE GUIDELINES FOR OPEN WATER DISPOSAL OF DREDGED MATERIAL

TABLE 6: 10-Place Pollutants Program
1987 Canagagigue Creek Study
Sediment - Geochemical Distribution of Metals
UNITS: ug/g, Dry Weight
(MAY-JUNE)

ALUMINUM

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	0.12	25.9	< 0.1	758	1130	19300	24400	21214
CANAGAGIGUE CREEK	0002	< 0.01	31.1	4.4	273	1110	11800	16200	13219
CANAGAGIGUE CREEK	0006	1.52	26.5	0.1	257	1270	13300	14800	14854
CANAGAGIGUE CREEK	0003	0.03	27.2	3.9	205	1200	12700	16700	14136
CANAGAGIGUE CREEK	0004	0.36	25.5	2.2	285	906	8360	14000	9579
CANAGAGIGUE CREEK	0005	0.05	27.2	2.8	324	1030	11100	14100	12484
CANAGAGIGUE CREEK	0007	0.43	40.4	9.0	539	2240	18400	21200	21228

KEY < Less than detection limit

ZINC

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	< 0.02	1.6	2.2	7.9	15.1	47.9	83.2	74.7
CANAGAGIGUE CREEK	0002	< 0.02	3.1	3.7	5.6	22.6	34.4	75.0	59.4
CANAGAGIGUE CREEK	0006	0.06	1.5	2.6	13.2	23.7	30.0	69.5	70.2
CANAGAGIGUE CREEK	0003	< 0.02	2.8	4.0	9.3	20.8	31.0	72.0	67.9
CANAGAGIGUE CREEK	0004	< 0.02	2.3	4.4	11.8	21.5	26.6	73.4	66.6
CANAGAGIGUE CREEK	0005	< 0.02	2.3	5.5	23.6	20.3	30.4	78.8	82.1
CANAGAGIGUE CREEK	0007	0.04	1.5	5.5	9.6	28.2	45.2	84.7	90.0

KEY < Less than detection limit

LEAD

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	< 0.05	< 3.0	4.0	6.0	8	5.0	23	23
CANAGAGIGUE CREEK	0002	< 0.05	< 2.0	< 2.0	4.0	18	5.0	30	31
CANAGAGIGUE CREEK	0006	< 0.05	< 3.0	4.0	6.0	18	5.0	33	33
CANAGAGIGUE CREEK	0003	< 0.05	< 3.0	< 2.0	4.0	16	5.0	28	27
CANAGAGIGUE CREEK	0004	< 0.05	< 3.0	< 2.0	6.0	14	< 3.0	28	25
CANAGAGIGUE CREEK	0005	< 0.05	< 2.0	< 2.0	8.0	14	< 3.0	28	26
CANAGAGIGUE CREEK	0007	< 0.05	< 3.0	< 2.0	< 3.0	12	< 3.0	15	17

KEY < Less than detection limit

CADMIUM

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	< 0.01	0.7	< 0.4	< 0.4	0.7	< 0.5	< 0.5	1.4
CANAGAGIGUE CREEK	0002	< 0.01	< 0.4	< 0.4	< 0.4	1.0	< 0.5	< 0.5	1.4
CANAGAGIGUE CREEK	0006	< 0.01	< 0.4	< 0.4	0.6	< 0.4	< 0.5	< 0.5	0.6
CANAGAGIGUE CREEK	0003	< 0.01	0.7	< 0.4	< 0.4	0.9	< 0.5	< 0.5	1.6
CANAGAGIGUE CREEK	0004	< 0.01	0.6	< 0.4	0.7	1.1	< 0.5	< 0.5	2.4
CANAGAGIGUE CREEK	0005	< 0.01	< 0.4	< 0.4	0.6	< 0.4	< 0.5	< 0.5	0.6
CANAGAGIGUE CREEK	0007	< 0.01	< 0.4	< 0.4	0.5	< 0.4	< 0.5	< 0.5	0.9

KEY < Less than detection limit

COPPER

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	< 0.008	< 0.3	< 0.3	1.2	5.4	6.6	16.3	13.2
CANAGAGIGUE CREEK	0002	< 0.008	< 0.3	< 0.3	3.1	9.2	2.9	16.0	15.2
CANAGAGIGUE CREEK	0006	0.014	< 0.3	< 0.3	6.1	8.6	3.4	16.3	18.1
CANAGAGIGUE CREEK	0003	< 0.008	< 0.3	< 0.3	4.4	9.6	4.4	16.2	18.4
CANAGAGIGUE CREEK	0004	< 0.008	< 0.3	< 0.3	6.9	8.9	3.5	15.3	19.3
CANAGAGIGUE CREEK	0005	< 0.008	< 0.3	< 0.3	5.7	10.0	4.3	15.6	20.0
CANAGAGIGUE CREEK	0007	< 0.008	< 0.3	< 0.3	2.9	9.2	4.7	16.4	16.8

KEY < Less than detection limit

ARSENIC

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	0.003	0.064	0.199	0.239	0.431	1.090	3.000	1.959
CANAGAGIGUE CREEK	0002	0.007 <	0.040	0.088	0.119	0.583	0.879	1.830	1.869
CANAGAGIGUE CREEK	0006	-	0.084	0.111	0.187	0.555	1.120	2.150	1.973
CANAGAGIGUE CREEK	0003	0.003	0.064	0.111	0.119	0.531	1.120	2.100	1.881
CANAGAGIGUE CREEK	0004	0.003	0.064	0.131	0.167	0.407	0.699	2.050	1.484
CANAGAGIGUE CREEK	0005	0.004	0.064	0.179	0.088	0.431	1.150	2.050	1.840
CANAGAGIGUE CREEK	0007	0.005 <	0.040	0.267	0.383	0.723	1.750	2.500	3.023

KEY < Less than detection limit
- No data

NICKEL

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	0.07	5	4	< 2.0	3.0	9	13	23
CANAGAGIGUE CREEK	0002	< 0.05	3	4	3.0	4.0	5	11	19
CANAGAGIGUE CREEK	0006	0.06	3	3	4.0	3.0	6	11	19
CANAGAGIGUE CREEK	0003	< 0.05	3	3	< 2.0	5.0	6	10	19
CANAGAGIGUE CREEK	0004	0.07	5	3	5.0	6.0	5	10	24
CANAGAGIGUE CREEK	0005	0.06	5	3	< 2.0	< 2.0	6	10	16
CANAGAGIGUE CREEK	0007	0.08	4	3	3.0	< 2.0	9	15	19

KEY < Less than detection limit

MANGANESE

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	5.01	107.0	115	35.3	43.6	87.5	569	388.4
CANAGAGIGUE CREEK	0002	1.31	82.9	101	39.8	23.4	76.5	314	321.6
CANAGAGIGUE CREEK	0006	1.35	127.0	116	36.5	48.3	92.0	443	409.6
CANAGAGIGUE CREEK	0003	4.63	124.0	109	33.2	33.4	91.1	543	410.7
CANAGAGIGUE CREEK	0004	3.59	104.0	109	38.6	25.9	86.1	396	353.6
CANAGAGIGUE CREEK	0005	4.46	143.0	151	19.3	18.4	68.6	442	400.3
CANAGAGIGUE CREEK	0007	4.43	101.0	171	24.7	32.1	106.0	501	434.0

KEY < Less than detection limit

CHROMIUM

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	< 0.01	< 0.4	< 0.4	2.5	0.9	18.1	13.1	21.9
CANAGAGIGUE CREEK	0002	< 0.01	< 0.4	0.5	5.5	1.3	10.9	14.7	18.2
CANAGAGIGUE CREEK	0006	< 0.01	< 0.4	0.5	9.0	1.5	11.9	14.4	22.4
CANAGAGIGUE CREEK	0003	< 0.01	0.6	< 0.4	5.1	1.5	11.7	13.2	19.3
CANAGAGIGUE CREEK	0004	< 0.01	< 0.4	0.9	5.8	4.1	8.7	15.7	19.5
CANAGAGIGUE CREEK	0005	< 0.01	< 0.4	0.9	5.7	< 0.4	9.3	17.0	15.9
CANAGAGIGUE CREEK	0007	0.02	0.7	2.0	5.3	2.4	23.3	38.7	33.7

KEY < Less than detection limit

IRON

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	SUM
CANAGAGIGUE CREEK	0001	6.55	5.9	315	361	2610	13900	34500	17192
CANAGAGIGUE CREEK	0002	2.05	21.2	395	225	2560	8680	15100	11081
CANAGAGIGUE CREEK	0006	7.11	10.3	367	348	2990	10600	14800	14015
CANAGAGIGUE CREEK	0003	16.00	7.5	346	216	2680	10700	17500	13950
CANAGAGIGUE CREEK	0004	2.91	8.3	433	257	1990	9030	14200	11708
CANAGAGIGUE CREEK	0005	0.76	10.3	477	476	2260	8730	14000	11973
CANAGAGIGUE CREEK	0007	41.00	11.1	1050	504	4590	13900	22300	20093

KEY: < Less than detection limit

ABLE 9: In-Place Pollutants Program

1986 Grand River/Canagagigue Study

Sediment - PCB & Pesticides

Units: ng/g Dry Weight

(MAY-JUNE)

tation	Aldrin	A-BHC Hexa-chlorocyclo hexane	B-BHC Hexa-chlorocyclo hexane	G-BHC Hexa-chlorocyclo hexane	A-Chlordane	G-Chlordane	Dieldrin	DMDT Meth-oxychlor	Endo-sulfan I	Endo-sulfan II	Endrin	Endo-sulfan sulfate	Hepta-chlor-epoxide	Hepta-chlor	Mirex	Oxy-chlorodane	OP-DDT	PCB Total	PP-DDD	PP-DDE	PP-DDT	Hexa chlo benz
0001	<1	<1	< 1	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	< 20	< 5	< 1	< 5	<1
0002	<1	<1	< 1	7	<2	2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	10	< 20	150	38	375	<1
0006	<1	<1	3	6	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	< 20	140	50	6030	<1
0003	<1	<1	< 1	2	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	25	< 20	60	18	810	<1
0004	<1	<1	< 1	7	<2	2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	10	< 20	30	28	340	1
0005	<1	<1	< 1	5	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	30	< 20	30	44	95	<1

V: < LOWER THAN DETECTION LIMIT

- NO DATA

(OCTOBER)

Station	Aldrin	A-BHC Hexa-chlorocyclo hexane	B-BHC Hexa-chlorocyclo hexane	G-BHC Hexa-chlorocyclo hexane	A-Chlordane	G-Chlordane	Dieldrin	DMDT Meth-oxychlor	Endo-sulfan I	Endo-sulfan II	Endrin	Endo-sulfan sulfate	Hepta-chlor-epoxide	Hepta-chlor	Mirex	Oxy-chlorodane	OP-DDT	PCB Total	PP-DDD	PP-DDE	PP-DDT	Hexa-chloro-benzene
0001	<1	<1	< 1	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	< 20	< 5	< 1	< 5	<1
0002	<1	<1	< 1	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	< 20	300	26	85	<1
0006	<1	<1	2	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	P40	50	20	18	20	<1
0003	<1	<1	< 1	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	10	P40	65	60	46	150	<1
0004	<1	<1	< 1	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	< 20	25	23	45	<1
0005	<1	<1	< 1	<1	<2	<2	<2	<5	<2	<4	<4	<4	<1	<1	<5	< 2	< 5	< 20	10	16	15	<1

KEY: < LOWER THAN DETECTION LIMIT

- NO DATA

TABLE 10: In-Place Pollutants Program
1987 Canagagigue Creek Study
Sediment - PAHs
UNITS: ug/g. Dry Weight

(MAY-JUNE)

LOCATION	STATION	DIBENZO(a,h) ANTHRACENE		BENZO(g,h,i) PERYLENE		NAPHTHA-LENE		ACENAPH-THYLENE		ACENAPH-THENE		FLUORENE		PHENAN-THRENE		ANTHRACENE		FLUORAN-THRENE		PYRENE	BENZO(a) ANTHRACENE	CHRYSENE	BENZO(k) FLUORAN-THENE	BENZO(b) FLUORENE	BENZO(a) PYRENE		INDENO (1,2,3-cd) PYRENE		% RECOVERY			
																												ACENAPH-THENE	PHENAN-THRENE	CHRYSENE	PERYLENE
CANAGAGIGUE C.	0001	0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.09		0.01	<T	0.11		0.08	0.04	0.04	0.06	0.06	0.04	<T	0.04	<T	45.00	83.00	91.00	100.0
CANAGAGIGUE C.	0002	0.06		0.15		0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.39		0.05		0.54		0.41	0.22	0.20	0.34	0.34	0.17		0.13		58.00	99.00	90.00	90.0
CANAGAGIGUE C.	0006	0.04	<T	0.12		0.04		0.04	<T	0.04	<T	0.04	<T	0.29		0.20		0.44		0.36	0.16	0.15	0.14	0.14	0.12		0.11		47.00	77.00	77.00	82.0
CANAGAGIGUE C.	0003	0.04	<T	0.06		0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.14		0.20		0.18		0.13	0.09	0.06	0.08	0 08	0.06		0.06		50.00	84.00	84.00	89.0
CANAGAGIGUE C.	0004	0.04	<T	0.08		0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.14		0.01		0.27		0.20	0.11	0.08	0.11	0.11	0.08		0.08		51.00	89.00	98.00	101.0
CANAGAGIGUE C.	0005	0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.04	<T	0.08		0.01	<T	0.14		0.10	0.03	0.03	0.06	0.06	0.04	<T	0.04	<T	47.00	78.00	65.00	69.00

KEY: <T - A measurable trace amount

TABLE 11: In-Place Pollutants Program

1987 Canagagigue Creek Study (MAY-JUNE)

Sediment - Oganics

Units: ng/g Dry weight

	Station		Hexa-chloro ethane	1.3.5 Trichloro benzene	1.2.4 Trichloro benzene	Hexa Chloro-butadiene	1.2.3 Trichloro benzene	2.4.5 Trichloro toluene	2.3.6 Trichloro toluene	1.2.3.5 Tetrachloro benzene	1.2.4.5 Tetrachloro benzene	2.6 Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene
ANAGAGIGUE CREEK	0001	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0002	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0006	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0003	-	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0004	100	<1	<2	7	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0005	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1

EY: < LOWER THAN DETECTION LIMIT

- NO DATA

(OCTOBER)

	Station	Hexa-chloro ethane	1.3.5 Trichloro benzene	1.2.4 Trichloro benzene	Hexa Chloro-butadiene	1.2.3 Trichloro benzene	2.4.5 Trichloro toluene	2.3.6 Trichloro toluene	1.2.3.5 Tetrachloro benzene	1.2.4.5 Tetrachloro benzene	2.6 Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene
NAGAGIGUE CREEK	0001	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0002	<1	<2	4	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0006	<1	<2	< 2	<1	<2	<1	<1	<1	3	<1	<1	<1
	0003	<1	<2	3	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0004	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0005	<1	<2	10	<1	8	<1	<1	2	<1	<1	<1	<1

< LOWER THAN DETECTION LIMIT

TABLE 12: In-Place Pollutants Program
1987 Canagagigue Creek Study (MAY-JUNE)
Sediment - Chlorophenols
Units: ng/g. Dry Weight
(MAY-JUNE)

Location	Station	Trichlorophenol 234	245	246	Tetrachlorophenol 2345	2356	Penta-chlorophenol
CANAGAGIGUE CREEK	0001	<100	<50	<50	< 50	< 50	< 50
	0002	<100	<50	<50	< 50	< 50	< 50
	0006	<100	<50	<50	< 50	< 50	< 50
	0003	<100	<50	<50	< 50	< 50	< 50
	0004	<100	<50	<50	< 50	< 50	< 50
	0005	<100	<50	<50	< 50	< 50	< 50

KEY < LOWER THAN DETECTION LIMIT

TABLE 13. Benthic Invertebrates - Tissue-Sediment Concentration Ratios
Canagagigue Creek, 1987.

Station No.	Copper	Chromium	Mercury	Cadmium	Iron	Lead
0001	1.45	0.17	5.35	0.82	0.14	0.62
0002	1.37	0.16	1.95	1.84	0.10	0.68
0006	1.46	0.16	2.69	0.56	0.18	0.45
0003	2.96	0.22	4.13	2.01	0.21	0.71
0004	0.91	0.22	2.04	0.90	0.14	0.49
0005	0.79	0.16	1.77	0.69	0.12	0.37

Station No.	Zinc	Arsenic	Manganese	Aluminum	Nickel
0001	1.46	3.44	0.23	0.10	0.30
0002	3.99	4.17	0.17	0.07	0.34
0006	1.23	4.04	0.28	0.13	0.37
0003	2.96	8.87	0.28	0.14	0.21
0004	0.90	3.73	0.21	0.09	0.45
0005	0.85	2.97	0.18	0.07	0.32

Sediment concentrations used in the calculations were on a dry weight (ug/g) basis. Biota values used were wet weight converted to dry weight and corrected for gut contents according to the formula in Persaud et al (1987). Bioaccumulation Factors were computed according to the formula:

$$C_{ct} = C_{org} - (C_{sed} \times K_{ash}) \times (1 - K_{ash})^{-1}$$

where C_{ct} = gut corrected tissue concentration; C_{org} = organism (dry weight) contaminant concentration; C_{sed} = bulk sediment concentration and; K_{ash} = residue after ashing organism at 500° C (as a percentage).

Tissue-sediment concentration ratios were computed according to the formula:

$$\text{Ratio} = C_{ct} / C_{sed}$$

TABLE 14: In-Place Pollutants Program

1987 Canagagigue Creek Study

Benthic Invertebrates - Metals

UNITS: ug/g. Wet Weight (Not corrected for gut content)

(MAY-JUNE)

Station	Organism	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel
0001	Oligochaetes	3.60	0.66	0.028	0.075	464	1.96	16.3	1.83	18.46	226	0.51
0001	Oligochaetes	4.17	0.84	0.022	0.067	564	1.68	16.7	1.16	21.57	290	0.73
0002	Oligochaetes	5.82	0.65	0.024	0.164	292	4.15	57.1	1.23	11.51	135	0.57
0006	Oligochaetes	4.83	0.64	0.021	0.049	447	2.17	16.2	1.51	19.99	224	0.60
0003	Oligochaetes	7.46	0.63	0.032	0.082	352	1.60	23.8	1.61	15.40	147	0.57
0004	Oligochaetes	4.07	1.05	0.035	0.091	525	1.99	17.3	1.86	21.13	263	1.04
0005	Oligochaetes	3.96	0.89	0.034	0.098	527	2.05	16.5	1.88	22.71	276	0.78
0005	Oligochaetes	3.16	0.76	0.032	0.051	415	1.27	15.9	1.00	17.74	207	0.83

UNITS: ug/g. Dry Weight. Corrected for gut contents

Station		Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel
0001	Oligochaetes	24.66	4.12	0.161	0.444	2724	11.25	104.9	9.627	114.15	1257	3.64
0002	Oligochaetes	36.88	3.51	0.156	1.048	1466	25.71	367.6	7.922	63.26	599	3.42
0006	Oligochaetes	30.65	3.49	0.135	0.301	2480	13.19	102.4	9.707	117.01	1184	3.60
0003	Oligochaetes	47.42	3.74	0.206	0.522	2084	10.01	151.1	11.535	92.89	836	3.35
0004	Oligochaetes	25.55	6.04	0.224	0.570	2690	12.23	108.3	11.930	131.84	1323	6.35
0005	Oligochaetes	22.25	4.93	0.213	0.464	2471	9.97	101.6	9.221	113.73	1121	4.78

TABLE 15: In-Place Pollutants Program

1987 Canagagigue Creek Study

Benthic Invertebrates - PCBs & Pesticides

UNITS: UG/G. Wet Weight (Not corrected for gut content)

(MAY-JUNE)

Station	Organism	HCB	Hepta-chlor	Hepta-chlor epoxide	Aldrin	Mirex	a-BHC	b-BHC	d-BHC	A-Chlordane	G-Chlordane	PCB	pp-DDE	pp-DDD	pp-DDT	op-DDT	Endo-Sulfan I	Endo-Sulfan II	Dieldrin	Endrin	Endo-Sulfan Sulfate	Methoxy-chlor	% Lipid	% Ash
0001	Oligochaetes	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	0.002	<0.001	< 0.001	< 0.01	< 0.001	0.006	< 0.001	< 0.001	< 0.001	0.007	< 0.001	< 0.003	< 0.001	< 0.001	0.504	4.11
0001	Oligochaetes	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.010	< 0.001	< 0.001	0.890	2.13
0002	Oligochaetes	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	0.004	<0.001	< 0.001	0.21	0.004	0.005	< 0.001	< 0.001	< 0.001	0.011	< 0.001	< 0.010	< 0.001	< 0.001	0.522	2.97
0006	Oligochaetes	0.003	<0.001	<0.002	<0.001	<0.002	0.003	<0.001	<0.001	<0.001	< 0.001	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.010	0.003	< 0.001	0.513	2.93
0006	Oligochaetes	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.010	< 0.001	< 0.001	0.616	2.82
0006	Leeches	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.01	< 0.001	0.006	< 0.001	< 0.001	< 0.001	0.004	< 0.001	< 0.010	< 0.001	< 0.001	0.554	0.37
0006	Dragonfly	<0.001	<0.001	<0.002	<0.001	0.038	<0.001	<0.001	0.004	<0.001	< 0.001	< 0.01	0.010	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.010	< 0.001	< 0.001	1.370	1.42
0003	Oligochaetes	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	0.003	<0.001	< 0.001	0.06	0.004	0.006	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.010	< 0.001	< 0.001	0.582	1.65
0004	Oligochaetes	<0.001	0.013	<0.002	<0.001	<0.002	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.004	< 0.001	< 0.010	< 0.001	< 0.001	0.704	2.07
0004	Leeches	<0.001	<0.001	<0.002	<0.001	<0.002	0.009	<0.001	<0.001	<0.001	< 0.001	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.010	0.009	< 0.001	1.115	2.75
0005	Oligochaetes	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	0.008	<0.001	< 0.001	< 0.01	0.008	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.008	< 0.006	< 0.001	< 0.001	0.005	0.97
0005	Chironomids	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	0.013	<0.001	< 0.001	< 0.01	< 0.001	0.013	< 0.001	< 0.001	< 0.001	0.009	< 0.001	< 0.002	< 0.001	< 0.001	.0.007	2.66
0005	Leeches	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.001	0.006	<0.001	< 0.001	< 0.01	0.004	0.008	< 0.001	< 0.001	< 0.001	0.002	0.002	< 0.010	< 0.001	< 0.001	0.010	0.98

KEY: < Less than detection limit

- No data

TABLE 16: In-Place Pollutants Program

1987 Canagagigue Creek Study

Benthic Invertebrates - Chlorinated Aromatics

UNITS: ug/g. Wet Weight (Not corrected for gut content)

MAY-JUNE

Station	Biota	Hexa-chloro-ethane	135-Trichloro-benzene	124-Trichloro-benzene	Hexa-chloro-butadiene	123-Trichloro-benzene	245-Trichloro-toluene	236-Trichloro-toluene	1235-Tetrachloro-benzene	1245-Tetrachloro-benzene	26A Trichloro-toluene	1234-Tetrachloro-benzene	Penta-chloro-benzene	Octa-chloro-Styrene	Toxaphene
0001	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.001	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0001	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0002	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.001	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0006	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0006	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0006	Leeches	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0006	Dragonfly	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0003	Oligochaetes	< 0.001	< 0.002	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0004	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0004	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.003	< 0.001	-	< 0.01
0004	Leeches	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0005	Oligochaetes	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0005	Chironomids	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0005	Leeches	< 0.001	< 0.010	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01

KEY: < Less than detection limit

- No data

TABLE 17: In-Place Pollutants Program

1987 Canagagigue Creek Study

Benthic Invertebrates - Chlorophenols

UNITS: ug/g, Wet Weight (Not corrected for gut content)

(MAY-JUNE)

Station	Biota	234-Tri-Chlorophenol	2345-Tetra-Chlorophenol	2356-Tetra-Chlorophenol	345-Tri-Chlorophenol	246-Tri-Chlorophenol	Penta-Chlorophenol
0001	Oligochaetes	< 0.010	< 0.003	< 0.005	< 0.010	< 0.010	< 0.005
0001	Oligochaetes	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0002	Oligochaetes	< 0.010	< 0.005	< 0.002	0.142	< 0.002	0.047
0006	Oligochaetes	< 0.006	< 0.005	< 0.008	0.088	0.021	0.061
0006	Oligochaetes	< 0.010	< 0.005	< 0.005	0.119	< 0.009	0.044
0006	Leeches	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.001
0006	Dragonfly	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0003	Oligochaetes	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0004	Oligochaetes	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0004	Oligochaetes	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0004	Oligochaetes	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.002
0004	Leeches	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0005	Oligochaetes	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.004
0005	Chironomids	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005
0009	Leeches	< 0.010	< 0.005	< 0.005	< 0.010	< 0.010	0.005

KEY: < Less than detection limit

TABLE 18: In-Place Pollutants Program
1987 Canagagigue Cr. Study
Fish - Metals
Units: mg/g. Wet Weight
(MAY-JUNE)

Station	AGE	Species	Copper Cu	Chromium Cr	Mercury Hg	Cadmium Cd	Iron Fe	Lead Pb	Zinc Zn	Arsenic As	Manganese Mn	Alunium Al	Nickle Ni	% Solids
0001	1-2 YR	RAINBOW DARTER	4.74	0.78	0.096	0.008	33	0.12	33.9	0.35	17.70	18	0.57	28.65
0001	2 YR	LONGNOSE DACE	3.66	0.56	0.118	0.011	30	0.03	32.8	0.34	5.63	11	0.33	25.34
0001	1 YR	EMERALD SHINER	4.43	0.76	0.048	0.015	28	0.06	67.0	0.64	4.09	17	0.56	32.30
0002	1-2 YR	WHITE SUCKER	6.13	0.76	0.052	0.022	37	0.45	27.9	0.61	8.97	21	0.67	25.76
0002	1-2 YR	WHITE SUCKER	6.36	0.62	0.056	0.026	80	0.45	22.5	0.19	6.00	46	0.60	24.13
0006	2 YR	EMERALD SHINER	4.54	0.55	0.094	0.005	36	0.09	50.3	0.09	2.98	19	0.44	27.97
0006	2 YR	EMERALD SHINER	3.86	0.54	0.092	0.004	35	0.08	52.1	0.12	3.21	17	0.39	28.38
0003	1 YR	EMERALD SHINER	3.72	0.49	0.082	0.010	66	0.11	44.2	0.17	3.54	32	0.25	31.21
0004	1-2 YR	WHITE SUCKER	6.19	0.73	0.063	0.028	136	1.02	29.5	0.38	11.82	69	0.58	24.63
0004	1 YR	EMERALD SHINER	5.83	0.77	0.097	0.009	42	0.10	55.8	0.42	3.46	23	0.57	31.34
0005	1-2 YR	LONGNOSE DACE	4.34	0.68	0.144	0.005	59	0.10	34.1	0.60	9.29	19	0.44	29.28
0005	1-2 YR	WHITE SUCKER	5.06	0.71	0.072	0.013	38	0.40	25.9	0.36	10.97	18	0.44	25.68

TABLE 19: In-Place Pollutants Program
1987 Canagagigue Cr. Study
Fish - PCBs and Pesticides
Units: ug/g wet weight

Station	Species	Aldrin	a-BHC Hexa-chlorocyclo-hexane	B-BHC Hexa-chlorocyclo-hexane	A-Chlordane	G-Chlordane	Dieldrin	DMDT Methoxy-chlor	Endo-Sulfan I	Endo-Sulfan II	Endrin	Endo sulfan sulphate	Hepta-chlor-epoxide	Hepta-Chlor-?	Mirex	Oxychlord	op-DDT	PCB (total)	pp-DDD	pp-DDE	pp-DDT
0001	Rainrow Darter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.00	0.000	0.091	0.000
0001	Longnose Dace	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.17	0.000	0.000	0.000
0001	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.14	0.000	0.000	0.000
0002	White Sucker	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	NA	0.000	0.23	0.000	0.082	0.000
0006	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.59	0.000	0.148	0.000
0006	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.33	0.000	0.140	0.000
0003	Emerald Shiner	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	NA	0.000	0.52	0.000	0.196	0.000
0004	White Sucker	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.16	0.000	0.180	0.000
0004	Emerald Shiner	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	NA	0.000	1.91	0.000	0.219	0.000
0005	Longnose Dace	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.00	0.000	0.000	0.000
0005	White Sucker	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	NA	0.000	0.22	0.000	0.000	0.000

TABLE 20: In-Place Pollutants Program
1987 Canagagigue Creek Study
Fish - Chlorinated Aromatics
Units: ug/g wet weight

Station #	Species	Hexa-chloro-ethane	1,3,5 Trichloro-benzene	1,2,4 Trichloro-benzene	1,2,3 Trichloro-benzene	Hexa-chloro-butadiene	2,4,5 Trichloro-toluene	2,3,6 Trichloro-toluene	2,6a Trichloro-toluene	1,2,3,5 Tetrachloro-benzene	1,2,4,5 Tetrchloro-benzene	1,2,3,4 Tetrachloro-benzene	Penta-chloro-benzene	Octachloro-Styrene	Toxaphene
0001	Rainrow Darter	0.000	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0001	Longnose Dace	0.000	0.035	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0001	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0002	White Sucker	0.000	0.051	0.000	0.000	0.009	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0006	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0006	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0003	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0004	White Sucker	0.000	0.000	0.000	0.004	0.000	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0004	Emerald Shiner	0.000	0.076	0.000	0.000	0.022	NA	NA	0.000	0.000	0.000	0.031	0.000	0.000	0.000
0005	Longnose Dace	0.004	0.000	0.000	0.000	0.006	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0005	White Sucker	0.000	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000	0.000	0.029	0.000	0.000	0.000

TABLE 21: In-Place Pollutants Program

1987 Canagagigue Cr. Study

Fish - Chlorophenols

Units: ug/g wet weight

Station	Species	Trichlorophenol					Penta-chlorophenol
		234	245	246	2345	2356	
0001	Rainrow Darter	0.000	0.000	0.000	0.000	0.000	0.032
0001	Longnose Dace	0.000	0.000	0.000	0.000	0.000	0.018
0001	Emerald Shiner	0.000	0.000	0.000	0.000	0.000	0.054
0002	White Sucker	0.000	0.000	0.032	0.000	0.000	0.039
0006	Emerald Shiner	0.000	0.000	0.014	0.000	0.000	0.016
0006	Emerald Shiner	0.000	0.000	0.013	0.000	0.000	0.013
0003	Emerald Shiner	0.000	0.000	0.015	0.000	0.000	0.011
0004	White Sucker	0.000	0.000	0.009	0.000	0.000	0.009
0004	Emerald Shiner	0.000	0.000	0.041	0.000	0.000	0.042
0005	Longnose Dace	0.000	0.000	0.000	0.000	0.000	0.022
0005	White Sucker	0.000	0.000	0.008	0.000	0.000	0.016

TABLE 22: In-Place Pollutants Program

1987 Canagagigue Creek Study

Sediment Bioassay Bioaccumulation Results: Metals

UNITS: ug/g, Wet Weight (Not corrected for gut content)

LOCATION	STATION	ORGANISM	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Zn
GRAND R.- CAN. CR.	CONTROL	MAYFLIES	194	0.16	0.172	0.75	1.59	364	0.69	20.6	0.015	0.51	23.1
GRAND R.- CAN. CR.	CONTROL	MAYFLIES	207	0.18	0.166	0.89	1.72	383	0.67	25.2	0.012	0.78	20.8
GRAND R.- CAN. CR.	CONTROL A	FATHEADS	46	0.11	0.040	0.44	5.26	81	0.16	3.1	0.200	0.24	35.1
GRAND R.- CAN. CR.	PRECONTROL	MAYFLIES	111	0.15	0.246	0.77	1.76	208	0.32	9.6	0.014	0.62	24.6
GRAND R.- CAN. CR.	PRECONTROL	FATHEADS	7	0.06	0.067	0.36	6.08	20	0.34	1.3	0.221	< 0.05	37.1
GRAND R.- CAN. CR.	PRECONTROL	FATHEADS	8	0.06	0.041	0.39	5.84	19	0.03	1.3	0.246	0.22	34.0
CANAGAGIGUE CREEK	1	MAYFLIES	291	0.33	0.117	0.79	2.57	597	1.09	26.9	0.010	0.61	20.1
CANAGAGIGUE CREEK	1A	FATHEADS	48	0.10	0.082	0.46	6.02	94	0.18	4.0	0.013	0.22	36.9
CANAGAGIGUE CREEK	2	MAYFLIES	197	0.24	0.174	0.72	3.00	419	1.39	28.6	0.023	0.49	23.6
CANAGAGIGUE CREEK	6	MAYFLIES	153	0.22	0.219	0.94	2.46	322	0.83	35.9	0.022	0.51	27.2
CANAGAGIGUE CREEK	6	MAYFLIES	394	0.28	0.181	1.42	3.96	677	1.91	48.6	0.024	0.98	26.4
CANAGAGIGUE CREEK	6A	FATHEADS	126	0.08	0.100	0.70	6.15	221	1.06	12.4	0.220	0.31	34.3
CANAGAGIGUE CREEK	3	MAYFLIES	264	0.26	0.125	0.80	3.12	542	1.27	23.3	0.192	0.60	22.4
CANAGAGIGUE CREEK	3A	FATHEADS	34	< 0.05	0.105	0.45	6.43	79	0.17	2.3	0.244	0.23	33.5
CANAGAGIGUE CREEK	3A	FATHEADS	15	0.06	0.092	0.40	6.72	34	0.06	1.1	0.258	< 0.07	33.2
CANAGAGIGUE CREEK	4	MAYFLIES	228	0.28	0.152	0.90	2.68	449	0.94	24.9	0.019	0.68	23.1
CANAGAGIGUE CREEK	4A	FATHEADS	45	< 0.05	0.075	0.31	5.74	85	0.19	4.5	0.253	0.15	40.7
CANAGAGIGUE CREEK	5	MAYFLIES	190	0.15	0.130	0.87	2.64	444	0.78	24.6	0.015	0.52	23.4
CANAGAGIGUE CREEK	5A	FATHEADS	50	< 0.05	0.057	0.46	4.55	112	0.20	4.1	0.245	0.20	36.7

KEY: < Less than detection limit

TABLE 23: In-Place Pollutants Program

1987 Canagagigue Creek Study

Sediment Bioassay Bioaccumulation Results: PCBs & Pesticides

UNITS: ug/g, Wet Weight (Not corrected for gut content)

STATION	ORGANISM	WEIGHT g	% LIPID	% ASH	HCB	HEPTA CHLOR	HEPTA. EPOX.	ALDRIN	MIREX	a-BHC	B-BHC	d-BHC	ALPHA-CHLORDANE	GAMMA-CHLORDANE	pp-DDE	pp-DDD	pp-DDT	op-DDT	a-ENDO-SULFAN	B-ENDO-SULFAN	DIELDRIN	ENDRIN	ENDO-SO4	METHOXY-CHLOR	PCB
CONTROL	MAYFLIES	1.737	2.112	1.63	0.003	< 0.001	<0.002	<0.001	<0.002	<0.001	<0.0012	<0.0012	<0.0012	0.0012	0.007	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.00	<0.001	< 0.001	0.01
CONTROL A	FATHEADS	1.764	2.732	2.74	0.005	< 0.001	<0.002	<0.001	<0.002	<0.001	<0.0012	<0.0012	<0.0012	0.0012	0.011	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.00	<0.001	< 0.001	0.01
PRECONTROL	MAYFLIES	0.724	1.906	1.48	0.017	< 0.001	<0.002	<0.001	<0.002	<0.001	<0.0012	<0.0012	<0.0012	0.0012	0.030	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.00	<0.001	< 0.001	0.01
PRECONTROL	FATHEADS	3.227	5.401	2.35	0.006	< 0.001	<0.002	<0.001	<0.002	<0.001	<0.0012	<0.0012	<0.0012	0.0012	0.005	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.01	<0.001	< 0.001	0.01
1	MAYFLIES	1.267	2.061	1.91	<0.001	< 0.001	<0.002	0.005	<0.002	<0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.007	<0.001	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	<0.001	< 0.001	< 0.01
1A	FATHEADS	1.840	3.816	2.95	<0.001	< 0.001	<0.002	<0.001	<0.002	<0.001	< 0.001	< 0.001	< 0.001	< 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	<0.001	< 0.001	< 0.01
2	MAYFLIES	0.756	1.853	1.88	<0.001	< 0.001	<0.002	0.039	<0.002	<0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.082	0.042	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	<0.001	< 0.001	< 0.01
6	MAYFLIES	1.585	1.798	2.33	0.021	< 0.001	<0.002	0.005	<0.002	0.014	< 0.001	< 0.001	< 0.001	< 0.001	0.033	0.017	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	0.014	< 0.001	< 0.01
6A	FATHEADS	1.770	3.553	3.36	0.011	0.003	<0.002	<0.001	<0.002	<0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.026	0.084	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	<0.001	< 0.001	< 0.01
3	MAYFLIES	1.501	1.386	1.79	0.004	0.002	<0.002	0.005	<0.002	0.007	< 0.001	0.011	< 0.001	< 0.001	0.062	0.031	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	0.007	< 0.001	< 0.01
3A	FATHEADS	2.643	3.254	2.67	0.002	0.003	0.004	0.005	<0.002	0.002	< 0.001	0.009	0.004	0.004	0.021	<0.001	0.027	<0.001	0.004	< 0.001	0.003	<0.01	0.002	< 0.001	< 0.01
4	MAYFLIES	1.616	1.633	2.30	0.002	0.007	0.010	0.012	<0.002	0.004	< 0.001	0.016	< 0.001	< 0.001	0.056	0.038	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	0.004	< 0.001	< 0.01
4A	FATHEADS	1.536	4.381	3.33	<0.001	< 0.001	<0.002	0.060	<0.002	<0.001	< 0.001	0.015	< 0.001	< 0.001	0.110	0.162	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	<0.001	< 0.001	< 0.01
5	MAYFLIES	1.709	1.954	1.70	0.002	< 0.001	<0.002	0.005	<0.002	0.003	< 0.001	< 0.001	< 0.001	< 0.001	0.050	0.013	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	0.003	< 0.001	< 0.01
5A	FATHEADS	3.454	3.208	2.08	0.002	< 0.001	<0.002	<0.001	<0.002	0.005	< 0.001	< 0.001	< 0.001	< 0.001	0.022	0.039	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.01	0.005	< 0.001	< 0.01

KEY: < Less than detection limit

- No data

TABLE 24: In-Place Pollutants Program

1987 Canagagigue Creek Study

Sediment Bioassay Bioaccumulation Results: Chlorinated Aromatics

UNITS: ug/g. Wet Weight (Not corrected for gut content)

STATION	ORGANISM	HEXACHLORO -ETHANE	135-TCB	124-TCB	HEXACHLORO -BUTADIENE	123-TCB	245-TCT	236-TCT	1235-TCB	1245-TCB	26a-TCT	1234-TCB	PENTACHLORO BENZENE	OCTACHLORO STYRENE	TOXAPHENE
CONTROL	MAYFLIES	< 0.001	< 0.010	< 0.010	0.006	< 0.005	-	-	< 0.001	0.001	<0.010	0.030	0.020	-	< 0.01
CONTROL A	FATHEADS	< 0.001	0.336	< 0.010	0.077	0.077	-	-	< 0.001	0.001	<0.010	0.058	0.029	-	< 0.01
PRECONTROL	MAYFLIES	0.023	< 0.010	< 0.010	0.029	0.029	-	-	0.010	0.010	<0.010	< 0.001	0.050	-	< 0.01
PRECONTROL	FATHEADS	< 0.001	0.238	< 0.010	0.053	0.053	-	-	< 0.001	0.001	<0.010	0.037	0.067	-	< 0.01
1	MAYFLIES	0.012	< 0.010	< 0.010	0.021	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	0.037	-	< 0.01
1A	FATHEADS	< 0.001	< 0.010	< 0.010	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
2	MAYFLIES	0.025	< 0.010	< 0.010	0.032	0.032	-	-	< 0.001	< 0.001	< 0.01	< 0.001	0.042	-	< 0.01
6	MAYFLIES	< 0.001	0.350	< 0.010	0.028	0.028	-	-	< 0.001	< 0.000	< 0.01	< 0.001	0.029	-	< 0.01
6A	FATHEADS	< 0.001	0.443	< 0.010	0.073	0.073	-	-	< 0.001	< 0.000	< 0.01	< 0.001	0.029	-	< 0.01
3	MAYFLIES	< 0.001	0.248	< 0.010	0.038	< 0.005	-	-	< 0.001	< 0.001	< 0.01	0.064	0.027	-	< 0.01
3A	FATHEADS	< 0.001	0.075	< 0.010	0.016	0.016	-	-	< 0.001	< 0.001	< 0.01	0.014	0.023	-	< 0.01
4	MAYFLIES	< 0.001	0.354	< 0.010	0.037	0.037	-	-	< 0.001	< 0.001	< 0.01	0.049	0.015	-	< 0.01
4A	FATHEADS	< 0.001	0.412	< 0.010	0.175	0.175	-	-	< 0.001	< 0.001	< 0.01	< 0.001	0.050	-	< 0.01
5	MAYFLIES	0.010	< 0.010	0.127	0.016	0.016	-	-	0.005	0.005	< 0.01	< 0.001	0.012	-	< 0.01
5A	FATHEADS	0.004	< 0.010	< 0.010	0.005	< 0.005	-	-	< 0.001	< 0.000	< 0.01	< 0.001	0.005	-	< 0.01

KEY: < Less than detection limit

- No data

TABLE 25: In-Place Pollutants Program

1987 Canagagigue Creek Study

Sediment Bioassay Bioaccumulation Results: Chlorophenols

UNITS: ug/g, Wet Weight (Not corrected for gut content)

STATION	ORGANISM	234-TRI-CHLOROPHENOL	2345-TETRA-CHLOROPHENOL	2356-TETRA-CHLOROPHENOL	345-TRI-CHLOROPHENOL	246-TRI-CHLOROPHENOL	PENTA-CHLOROPHENOL
CONTROL	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
CONTROL A	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
PRECONTROL	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	0.053
PRECONTROL	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
1	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
1A	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
2	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
6	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
6A	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
3	MAYFLIES	< 0.01	< 0.005	< 0.005	0.014	< 0.01	0.004
3A	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
4	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
4A	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
5	MAYFLIES	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005
5A	FATHEADS	< 0.01	< 0.005	< 0.005	< 0.010	< 0.01	< 0.005

KEY: < Less than detection limit

TABLE 26: Correlation Coefficients (Spearman Rank) for Sediment Metals and Organic Carbon and for Sediment Metals and Corresponding Invertebrate Tissue Levels (significance level in parentheses).

	Sediment TOC May	Sediment % Silt	Sediment TOC Oct
sediment copper	-.0580 (.8968)	.8117 (.0695)	.6000 (.1797)
sediment chromium	.0580 (.8968)	**.9276** (.0381)	.1429 (.7494)
sediment mercury	.2319 (.6041)	.5798 (.1948)	.3714 (.4062)
sediment cadmium	-.0290 (.9483)	.8407 (.0601)	.8407 (.0601)
sediment iron	.0580 (.8968)	**.9276** (.0381)	**.9710** (.0299)
sediment lead	-.7714 (.0845)	.0857 (.8480)	.4857 (.2774)
sediment zinc	-.0580 (.8968)	.8117 (.0695)	.8286 (.0639)
sediment arsenic	.0857 (.8480)	**.9429** (.0350)	**.9429** (.0350)
sediment manganese	.0286 (.9491)	**.8857** (.0476)	.7143 (.1102)
sediment aluminum	.0580 (.8968)	**.9276** (.0381)	**.9856** (.0275)
sediment nickel	**.9429** (.0350)	.0857 (.8480)	**.9429** (.0350)

Silt correlation data from May-June survey.

Correlations significant at the 95% level appear in bold type.

TABLE 27: Correlation Coefficients (Spearman Rank) for Sediment Geochemical Fractions and Invertebrate Tissue Level (all calculations based on wet weight) (significance level in parentheses).

	IW	F1	F2	F3	F4	Res	Bulk
biota zinc	-	8382 (.0609)	-.0290 (.9483)	-.8117 (.0695)	.1449 (.7459)	-.3479 (.4367)	-.0290 (.9486)
biota manganese	.3143 (.4822)	.2571 (.5653)	.2000 (.6547)	-.1429 (.7494)	-.1429 (.7494)	-.2571 (.5653)	.0286 (.9491)
biota aluminum	.6088 (.1734)	**-.8986** (.0445)	-.7143 (.1102)	.6571 (.1417)	-.4857 (.2774)	-.2000 (.6547)	-.2319 (.6041)
biota arsenic	--	.5071 (.2568)	.1160 (.7954)	.3189 (.4758)	-.5218 (.2433)	-.2319 (.6041)	.3189 (.4758)
biota iron	-.1429 (.7494)	-.5218 (.2433)	.2000 (.6547)	.7143 (.1102)	-.4857 (.2774)	.3143 (.4822)	-.2571 (.5653)
biota copper	.1309 (.7697)	--	--	-.0857 (.8480)	.0857 (.8480)	-.3143 (.4822)	.2029 (.6500)
biota lead	--	-.5416 (.2671)	-.1904 (.7179)	-.5127 (.2989)	.4815 (.3336)	--	.3552 (.4896)
biota chromium	--	-.6547 (.1432)	.7171 (.1088)	.2000 (.6547)	-.1160 (.7954)	-.6000 (.1797)	.6000 (.1797)
biota cadmium	--	-.0309 (.9450)	--	-.0926 (.8360)	.8407 (.0601)	--	--
biota nickel	-.3032 (.4978)	.1980 (.6579)	.4201 (.3476)	-.6776 (.1297)	-.5735 (.1997)	.1409 (.7527)	.0470 (.9164)

Correlations significant at the 95% level appear in bold type.

TABLE 28: DISTRIBUTION, DENSITY, AND BIOMASS ESTIMATES OF MAJOR MACROBENTHIC TAXA, CANAGAGIGUE CREEK, MAY-JUNE 1987.

All values are expressed on a per square meter basis. Biomass values calculated on wet weight basis.

	Station 0001		Station 0002		Station 0006		Station 0003		Station 0004		Station 0005	
	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)
ARTHROPODA												
Class Insecta												
O. Ephemeroptera											15	7.4649
O. Odonata												
O. Trichoptera												
O. Coleoptera	65	0.0256			38	0.0176	46	0.0552	169	0.0509	88	0.0218
O. Diptera												
F. Chironomidae	130	0.1536	184	0.0967	207	0.1154	15		736	0.7674	1,122	0.6414
F. Ceratopogonidae	54	0.0161			8	0.0032	46				15	0.0119
F. Tabanidae			15	0.0919	8	0.0644						
Class Crustacea												
O. Amphipoda												
O. Isopoda					23	0.0065	46	0.1996	15	0.0316		
MOLLUSCA												
Class Gastropoda			92	3.7417	69	0.7786					352	2.9438
Class Pelecypoda					31							
ANNELIDA												
Class Hirudinea			15	0.3208	15	0.1086			31	8.7797	191	0.8622
Class Oligochaeta	5,696	15.1740	12,580	22.2681	6,726	12.0453	2,926	3.6500	23,260	44.6154	8,132	16.5766
TOTAL # ORGANISMS	5,945		12,886		7,125		3,079		24,211		9,915	
TOTAL BIOMASS		15.3693		26.5192		13.1396		3.9048		54.2451		28.5226
CORRECTED BIOMASS (+ 10%)		16.91		29.17		14.45		4.29		59.67		31.37

TABLE 29: BENTHIC MACROINVERTEBRATE TAXA OF CANAGAGIGUE CREEK, MAY-JUNE, 1987

	STATION NUMBER (#/m²)					
	0001	0002	0006	0003	0004	0005
DIPTERA						
Chironomidae						
Chironominae						
Chironomus sp.	115		115		77	613
Chironomus plumosus grp.						
Phaenopsectra sp.						
Polypedilum (Pentapedilum) sp.						
Stictochironomus sp.		77				153
Tanytarsus sp.			192	77	383	
Orthocladiinae						
Cricotopus (Cricotopus) sp.			153		306	306
Orthocladius (Eudactylocladius) sp.			115			
Rheocricotopus sp.			77			
Tanypodinae						
Procladius sp.					77	
Ceratopogonidae						
Palpomyia sp.grp.	77			230		
COLEOPTERA						
Elmidae						
Dubiraphia sp.	38		115		230	
ISOPODA						
Asellidae						
Asellus sp.			38	153		
PELECYPODA						
Sphaeriidae						
Pisidium casertanum			192			
GASTROPODA						
Planorbidae						
Gyralus parvus		153				
Physidae						
Physella gyrina			38			1,073
HIRUDINEA						
Erpobdellidae						
Helobdella sp.			38			
H. stagnalis						306
OLIGOCHAETA						
Tubificidae						
Limnodrilus hoffmeisteri	3,428	3,754	3,792	2,452	24,822	3,984
L. udekemianus				383		
L. cervix/claparedianus	211					
Tubifex tubifex	115	536	2,298		3,294	
immatures with capilliform setae			1,149	689	843	
immatures without capilliform setae	440	1,839	1,149	2,068	3,294	2,452
Total Number of Organisms	**4,424**	**6,359**	**9,461**	**6,052**	**33,326**	**8,887**
Species Diversity (H')	**1.259**	**1.472**	**2.471**	**2.060**	**1.335**	**2.099**
Species Richness (S.R.)	**0.715**	**0.457**	**1.420**	**0.689**	**0.768**	**0.660**
Evenness (J')	**0.449**	**0.635**	**0.649**	**0.734**	**0.421**	**0.748**